Research on the Design of Enterprise Information Security Outsourcing Contract Based on Instalment Payment

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Abstract: In order to effectively alleviate the principal-agent problem caused by information asymmetry in the process of enterprise information security outsourcing, based on the idea of multi-agent, this paper constructs a calculation experimental model to classify and evaluate the business and pay on schedule, and introduces double incentive mechanism and simulation exploration into the information security outsourcing strategy. Help the entrusting enterprise reasonably set the important parameters involved in the outsourcing incentive mechanism. The research results show that if enterprises only rely on incentive intensity, it will lead to the marginal decline of incentive efficiency; At the same time, the incentive mode of adding benefit sharing ratio can make MSSP and enterprises become a community of interests, and promote the result of win-win cooperation to a greater extent; It is very important to choose an appropriate interval or value for the incentive intensity and benefit sharing ratio of enterprises.

Keywords: Information security outsourcing; computational experiments; incentive mechanism; multi-agent modeling

1 Introduction

Faced with the increasingly serious security threat situation and complex security management system, more and more enterprises outsource information security business to Managed Security Service Provider (MSSP) to reduce management cost and guarantee the security level of enterprise information system. However, the high technical threshold property of information security services and the invisibility of hackers' behavior make it difficult for enterprises to judge the performance and effort level of MSSP's investment in their information security business [1].

Domestic and foreign scholars have made rich research results in the field of information security outsourcing. Most scholars focus on optimizing the strategy or incentive mechanism of enterprise information security outsourcing, for example, Cezar et al [2] consider the influence of factors such as externality, risk dependency and service quality on enterprise information security outsourcing decision. Based on this, Feng et al [3] construct a game model to analyze the partial outsourcing strategy that enterprises can choose when there is information leakage

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risk. Other scholars point out that effective coordination of the cooperative relationship between enterprises and MSSP is crucial to the success of information security outsourcing, but enterprises and MSSP cannot observe each other's effort and willingness to commit well, and double moral hazard may occur [4]. To this end, Hui et al [5] designed bilateral refund contracts and showed that liability-driven bilateral service level agreements are more effective than the traditional approach of monitoring MSSP efforts in improving social welfare. However, although bilateral refund contracts can mitigate unilateral moral hazard, Lee et al [6] argue that firms' compensation from MSSP does not effectively address the dual moral hazard problem, and that simple bilateral compensation contracts do not enable MSSP and firms to achieve optimal levels of effort and willingness to commit, and that multilateral compensation contracts need to be introduced, i.e., in addition to firms paying MSSP an upfront fixed payment, they should also design ex-post payments. Based on this, Zhao et al [7] analyzed the influence of externality and default probability on ex post payment, and determined the amount of ex post payment in multilateral contract by the ratio between enterprise externality and investment efficiency. xiong et al [8] studied the incentive mechanism of information security outsourcing based on principal-agent theory, and showed that by setting reasonable fixed remuneration and compensation coefficient can maximize the incentive for MSSP to improve its service level.

The existing research results on enterprise information security outsourcing incentive mechanisms can largely promote MSSP to improve their efforts, but whether setting multilateral compensation contracts or introducing compensation coefficients, they are generally based on the perspective of the commissioning enterprise, with less consideration of MSSP's benefit-sharing preferences and psychological expectation changes. In addition, in the field of information security outsourcing research, numerical modeling is mostly used at present, and although the impact of each influence factor on the benefit and cost functions of both outsourcing parties can be projected, there are shortcomings such as not being able to dynamically demonstrate the evolutionary trends of both types of subjects, such as commissioning firms and MSSP [9]. As project problems become more complex and many models tend to be nonlinear and rapidly changing in nature, traditional mathematical modeling is difficult to portray the evolution between interacting subjects, so some scholars began to try to use computational experimental methods for decision optimization [10]. In addition, in the research on the optimization of incentive mechanism of project cluster phasing, scholars generally consider fixed percentage of incentive intensity, that is, only by adjusting the total amount of incentive intensity to increase the benefits of two-way subjects [11], but Zhang Ke et al [12] found that the incentive strategy of revenue sharing can better improve the benefits of entrusted owners to a greater extent and the contractor's effort level. Therefore, based on this paper, we construct a computational experimental model that classifies and evaluates the business and shares the benefits based on Multi-Agent idea. On the one hand, it helps enterprises to better ensure information security, and on the other hand, it also provides dynamic incentives for MSSP to improve their effort level, which promotes long-term cooperation between the two parties and achieves win-win situation.

2 Experimental model for computing dual incentive mechanism of information security outsourcing

2.1 Analysis of enterprise Agent attributes

For this service outsourcing business, the commissioning enterprise will pay a fixed amount to MSSP and then pay an incentive amount according to the completion of the outsourcing in advance, in order to achieve the optimization of the outsourcing service quality and its own benefit value-added. As a result, the utility function of the commissioning enterprise is shown in equation (1).

$$\mathrm{M}_{(t)} = W_{(t)} - [c + m(t - t')] \tag{1}$$

In equation (1): $\mathrm{M}_{(t)}$ refers to the enterprise's revenue under the optimization method of adopting fixed amount and incentive amount; $\mathrm{M}_{(t)}$ refers to the enterprise's revenue due to early completion; t refers to the contract setting period and t' refers to the actual completion period of security outsourcing; c refers to the initial enterprise's fixed amount paid to MSSP; F refers to the enterprise's incentive coefficient for MSSP to complete the task early and guarantee the quality ($m \geq 0$); $m(t - t')$ refers to the amount of incentive the MSSP receives for high effort levels.

However, considering the weak influence of the moderation approach relying on incentive intensity alone. As a result, this modeling will introduce the benefit-sharing ratio based on the previous model, so that the ratio of benefit sharing of the entrusted firm is p, and the ratio of benefits harvested by the MSSP due to the optimization of the outsourcing process is $1\text{-}\,p$,. Thus, the firm utility function after considering the incentive of utility sharing is shown in equation (2):

$$\mathrm{M}_{\mathrm{P}(t)} = pW_{(t)} - [c + m(t - t')] \tag{2}$$

In equation (2): $\mathrm{M}_{p(t)}$ refers to the corporate benefits brought by the optimization of incentive contracts; p denotes the benefit-sharing ratio set by the company; the remaining symbols are interpreted as in equation (1).

2.2 Analysis of Agent Attributes of Security Service Providers

The MSSP will continuously adjust its effort level throughout the outsourcing process by combining psychological judgment and the incentive intensity of the entrusted enterprise. It can be seen that the utility function of MSSP under corporate incentives is shown in equation (3).

$$N_{(x,t)} = c + m(t - t') - vx \quad (3)$$

In equation (3): refers to the benefit gained by the dynamically motivated MSSP; refers to the cost incurred by the MSSP for early completion and quality optimization ($v \geq 0$); and x refers to the effort level of the MSSP, i.e., the frequency of its effort for early completion of the outsourced task.

Similarly, it can be seen that the utility function of the MSSP after considering the introduction of the incentive strategy of utility sharing is shown in equation (4).

$$N_{P(x,t)} = c + m(t - t') - vx + W_{(t)}(1 - p) \quad (4)$$

In equation (4): $N_{P(x,t)}$ refers to the benefit for the MSSP after incentive contract optimization; the remaining symbols are explained in equation (3).

3 Case study

This study uses multi-agent modeling to construct a computational experimental model of information security outsourcing dual incentive mechanism, and the model takes the commissioning enterprise W and security service provider C as an example for computational experimental simulation. This study focuses on simulating the impact of the behavioral evolution of the firm and MSSP under the incentive intensity strategy and benefit sharing strategy on the effort level of MSSP and the total revenue of the firm. The parameter setting table is shown in Table 1.

Table 1 Modeling-related parameter settings

Variable name	meaning	Assignment
Numbers	Number of MSSPs	50
Times	Number of experimental iterations	100
n	Outsourcing stage	120
[0, t-t"]	Range of outsourcing days in advance	[0,50]
W(x)	Income of the enterprise due to early completion (10000 yuan)	[0,800]
c	Fixed amount paid to MSSP (10000 yuan)	100
m	Excitation coefficient	[0,4]
Q	Incentive intensity of entrusted enterprise (10000 yuan)	[0,180]
P	Benefit sharing ratio	[0.6,0.9]
X	MSSP effort level	[0,240]
V	Unit effort cost (10000 yuan)	[0,4]

3.1 Evolutionary analysis of MSSP behavior under different incentive strengths

Figure 1 shows the evolution law of the effort level of the security service provider (MSSP) under three different incentive intensities.

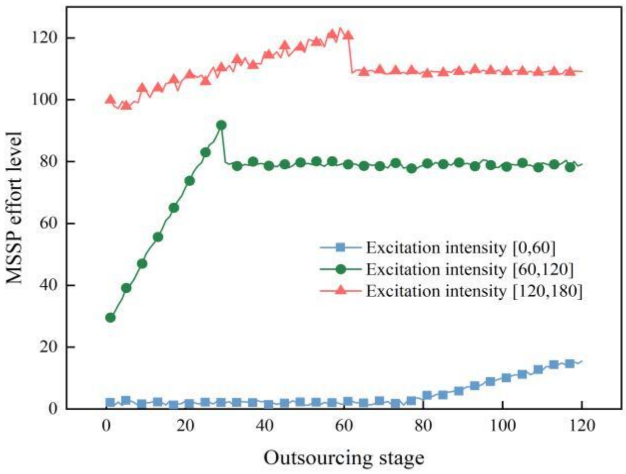

Figure 1 Trend of MSSP behavior under different incentive intensity of enterprises

With the increasing incentive intensity of entrusted enterprises, the effort level of MSSP gradually increases within a certain range until it reaches the equilibrium value. When Q changes from [0,60] to [60,120], the increase in the change of the total revenue of the firm is more obvious and the incentive efficiency of the MSSP effort level per unit incentive intensity increases by 1.8; while when Q changes from [60,120] to [120,180], the incentive efficiency of the MSSP effort level per unit incentive intensity increases by only 0.5. To sum up, when the incentive intensity is [60, 120], the incentive intensity has the greatest influence on the behavioral strategy of MSSP, while MSSP reaches the equilibrium value soon.

3.2 Analysis of the evolution of the total revenue of the enterprise under different incentive intensities

Figure 2 shows the evolution law of the total revenue of the enterprise entrusted under three different incentive intensities.

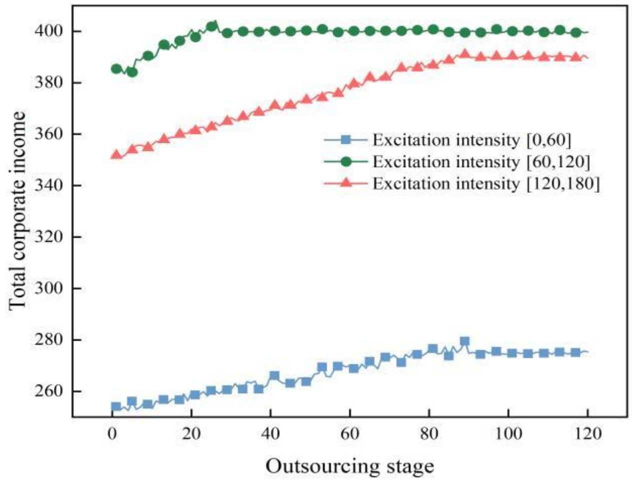

Figure 2 Trend of total enterprise revenue under different incentive intensity of enterprises

Different incentive intensities have different effects on the MSSP effort level, which leads to differences in the total revenue of the entrusted firms. In particular, the increase in the change in total firm benefits is more pronounced when Q changes from [0,60] to [60,120], and the incentive efficiency per unit incentive intensity on MSSP effort level is greater than the case when Q changes from [60,120) to [120,180). In summary, when the incentive intensity is [60, 120], the total benefit obtained by the firm optimizing the information security outsourcing incentive contract is the largest.

3.3 Evolutionary analysis of MSSP behavior under differentiated efficiency sharing ratios

The enterprise has the disadvantages of weak influence and slow feedback efficiency if it only relies on the incentive intensity to regulate the behavior mechanism of MSSP. Therefore, this study considers introducing the benefit sharing ratio along with the optimal incentive intensity to turn the two types of outsourcing subjects into a community of interests. Figures 3 show the evolution pattern of the effort level of MSSP for three different benefit sharing ratios.

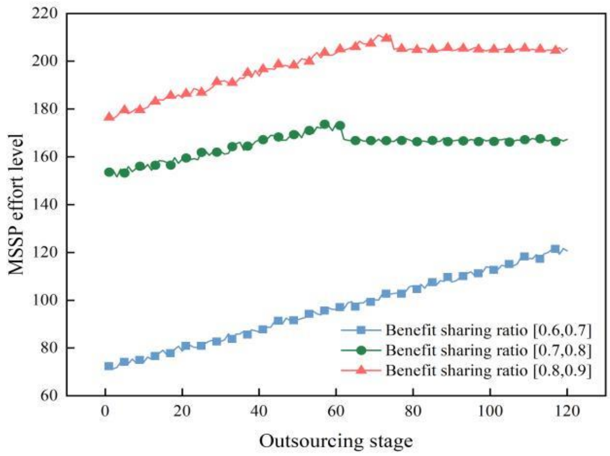

Figure 3 Simulation diagram of MSSP behavior under differentiated efficiency sharing ratio

In the process of increasing the efficiency sharing ratio P set by the enterprise, the MSSP effort level evolution curve then continues to grow within a certain limit before reaching the optimal equilibrium. In addition, the incentive efficiency of the unit benefit sharing ratio on the MSSP effort level increases and then decreases as P changes from [0.8,0.9] to [0.6,0.7]. Considering that in the outsourcing process the enterprise's goal is to maximize the efficiency, thus the enterprise sets the best incentive level for the MSSP effort level when the efficiency sharing ratio P=[0.7,0.8].

3.4 Evolutionary analysis of total firm benefits for differentiated efficiency sharing ratios

Figure 4 demonstrates the evolution of the firm's revenue at three different efficiency sharing ratios.

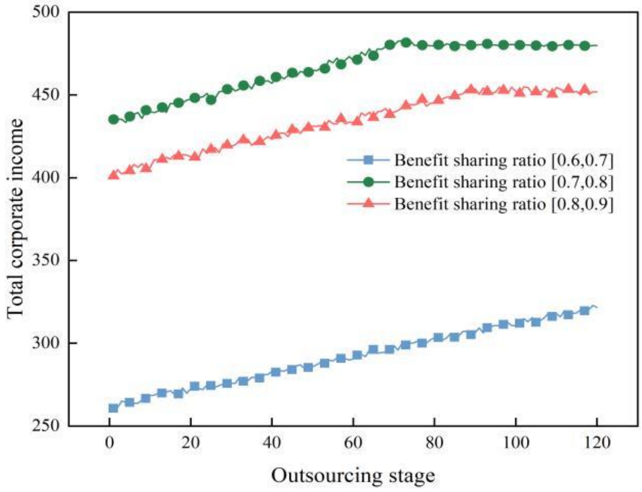

Figure 4 Simulation of total enterprise revenue under differentiated efficiency sharing ratio

As the efficiency sharing ratio P set by the firm can better urge MSSP to maintain high effort levels in the outsourcing process based on the incentive intensity, which in turn leads to a continuous decrease in the equilibrium value of total firm benefits. The incentive efficiency of the unit benefit sharing ratio on the MSSP effort level first increases and then decreases. In summary, the optimal interval for the benefit sharing ratio set by the company is P=[0.7,0.8], because at this time the total benefit gained by the company is the largest, and also the time to reach the optimal equilibrium value is the shortest.

4 Conclusion

Based on the perspective of enterprises and security service providers (MSSP), this paper uses computational experimental models to explore in depth the behavioral evolution of enterprises and MSSP under different incentive strengths as well as benefit sharing ratios, taking into account factors such as MSSP' behavioral strategy choices. The findings of this study are as follows.

(1) The optimized dual incentive mechanism can increase the total benefit of the enterprise and can reduce the post-operation and maintenance cost of the enterprise to a certain extent.

(2) By increasing the incentive intensity, enterprises can help MSSP improve their effort. However, the efficiency of the incentive is diminishing marginal benefit and the scope of influence is limited. But if we consider increasing the benefit sharing ratio to make MSSP and the company become a community of interests, we can achieve a greater degree of win-win cooperation.

(3) The incentive intensity and benefit-sharing ratio of the company should be chosen appropriately, and neither too high nor too low will optimize the total benefits for both parties.

Under the experimental setting scenario, the optimal incentive intensity range is [60,120] and the optimal benefit sharing ratio is P=[0.7,0.8].

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