

## Analysis of Adverse Selection for Motivation Mechanism in Engineering Project Cost Management

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**Abstract:** When the principal-agent contracts for design, supervision and construction of an engineering project are signed, the agent and the principal have hidden information. By means of tendering and negotiation, etc., it selects an agent offering a lower quotation which leads to “Bad money drives out good”, that is, commonly termed adverse selection problem. This study starts from the discussion of adverse selection and introduces a motivation mechanism to motivate the agent to exert initiative strategies more efficiently so that the agent can expose its hidden information automatically. The study also analyzes the project principal-agent strategies and finally uses a calculation example to demonstrate that the motivation mechanism in this study is efficient in inducing the agent to tell the truth, which aids the principal in selecting an agent with higher operational level.

**Keywords:** Adverse selection, cost management, engineering project, motivation mechanism, principal agent

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### INTRODUCTION

The development of engineering project cost control undergoes the calculation-type, control-type and value-creation-type stages and the cost management of an engineering project calls for a focus on value creation. If the project cost and agency expense are determined by means of traditional tendering, as the owner is overwhelmed by the agents in information, fails to know the true information about the project and the agents and is willing to pay the agency expense only according to the average project difficulty and the average agent level in market (Wei-Ying, 1997), higher-level agents will retreat from tendering whereas lower-level agents will enter bidding and this is the commonly-termed “lemon market”. Besides, a lump sum or unit price is often adopted for agency expense of current engineering projects, so the agent income changes not much and the agent (e.g., the designer) does not work so proactively, which is detrimental to value creation. Therefore, when signing a contract, one has to design a certain mechanism to acquire such information as actual project cost of the engineering project and reasonable agency expense and induce the agent to choose the action expected by the principal so as to create more value.

The objective of this study is to introduce a motivation mechanism to motivate the agent to exert initiative strategies more efficiently so that the agent can expose its hidden information automatically. The study also analyzes the project principal-agent strategies and finally uses a calculation example to demonstrate that

the motivation mechanism in this study is efficient in inducing the agent to tell the truth, which aids the principal in selecting an agent with higher operational level.

### LIMITATIONS OF TRADITIONAL AGENCY CONTRACTS

Nowadays, the agency of an engineering project is largely determined by means of tendering or contract negotiation; it is very difficult for the owner to get the agents' hidden information, it is unknown whether or not the agent has quoted a high agency expense and it is also very difficult to avoid bad behavior of the agents in tendering or contract negotiation; meanwhile the agent cannot be well motivated to take initiative to work hard in the future to create more value. With tendering being taken as an example, when a principal invites a tender for an engineering project, the price ceiling  $C$  will be set at first; suppose that an agent thinks after estimation that the actual project cost should be  $A$ , the agency fee will be collected at a rate  $q$  based on project cost in accordance with the national statutory agency fee standard for supervision, design and consultation,  $q = 1$  when the agent is the builder, thus, the agent's true agency expense will be  $qA$ ; the rate  $q$  is usually specified in the national charging standards or stated with a guide price and is relatively transparent in respective industry and it can be easily obtained by the principal. However, project cost varies greatly with engineering project; hence, the agent will usually hide the true project cost level  $A$  in bidding and quote a

higher project cost  $B$ , then the principal payment becomes  $qB$ , i.e., the principal income  $v = -qB$ . Suppose that the same agent team accepts the agency task uncontinuously with a certain interval, then some management cost and bidding cost will arise; if their sum is expressed by  $L$  and the bid-winning rate is represented by  $\omega$ , then the agent income  $u = \omega qB - L$  and it follows that:  $\partial u / \partial B = \omega q > 0$ ;  $\partial u / \partial q = \omega B > 0$ . Therefore, the agent income is an increasing function of project cost  $B$  and agency rate  $q$ , in other words, the agent will quote  $B$  and  $q$  as high as possible in bidding; as  $q$  is well known by the public, the agent will specifically quote  $B$  high, which brings risk to tendering; accordingly the principal will only be willing to pay agency expense with reference to the average market level, which will lower the criterion of price ceiling  $C$  and thus cause the problem of adverse selection (Mirrlees, 1999). In addition, without introducing a constraint mechanism, neither can the traditional tendering approach efficiently induce an agent to expose  $A$  automatically, nor can it motivate the agent to take initiative to work hard in future agency work, which will give rise to the problem of moral hazard.

### MOTIVATION MODEL

**Contract motivation model:** The mode of traditional agency contract fails to make an agent expose its hidden information automatically and will lead to the adverse selection problem, which is inconvenient for the owner to select an excellent agent and is detrimental to project cost and quality control. Hence, one shall add a motivation mechanism to an agency contract and introduce the constraint condition of “telling the truth” so that the agent can expose its hidden information is induced to select the principal-expected actions to create more value (Cheng and Zhang, 2006). The assumption for the improved motivation mechanism is such that, unlike the traditional tendering method where the fixed agency expense or fixed unit price of agency is determined at one time, the agency expense here is twice priced and the lower serves as the settlement price, thereby the principal’s negotiation advantage is extended to the project settlement stage. In tendering, besides a price ceiling  $C$ , the principal gives a deduction percentage  $p$ ; whereas the agent offers the first quotation  $B$  with a rate of  $q$  when bidding and determines the actual project cost  $A$  in an agreed manner when the project is completed. The agent expense consists of two parts: the first part is the basic agency fee  $q \cdot \min(A, B)$ , where,  $\min(A, B)$  represents  $A$  or  $B$  whichever is the minimum; to make the analysis easier, it is agreed that the settlement price  $A$  must be

less than  $B$ , consequently, the basic agency fee can be expressed by  $qA$ ; the second part is the saved amount  $D$  relative of cost  $C$  multiplied by a proportion of  $p$  to reward or punish the agent. The specific contract motivation model is:

$$I = qA + \frac{2DF - F^2}{D} p = q(C - D) + \frac{2DF - F^2}{D} p \quad (1)$$

where,

- $I$  = The total remuneration paid to the agent by the principal
- $D$  = The saved amount of actual project cost relative of price ceiling  $C$  previously set by the principal  $D = C - A$
- $F$  = The saved amount of the agent self-quoted project cost  $B$  relative of price ceiling  $C$  previously set by the principal  $F = C - B$
- $(2DF - F^2)/D$  = The deduction base for the agent income

The basic thinking of this contract motivation model is as follows: the more the actual saved amount of the project, the higher the principal income. Furthermore, a saved amount of the agent self-quoted project cost is added as a variable to measure the deduction remuneration in this model, which helps the agent expose its hidden information automatically and quote according to the measured  $A$  when bidding. The higher the credibility, work capability and professional level of an agent, the more income the agent will obtain. Another benefit is that, the agent can switch from passive state to active one in agency work. The feasibility of this model will be demonstrated in details in another study, whereas the focus of this study is to expound the model from the aspect of adverse selection.

**Analysis model for adverse selection problem:** The expected income when an agent participates in bidding can be expressed by  $u(1-L) - \omega L(1-\omega) = \omega L$  (Ying-Ying, 2007; Zhufang and Jiufeng, 2010; Ling *et al.*, 2011). According to Wen and Shu-Hua (2006) and Ding and Jia (2001) the actual saved amount of project cost  $D$ , estimated by the agent in bidding, is uniformly distributed in a given range. Here it is assumed that the actual saved cost estimated by the agent ranges within  $D \pm \varepsilon D$ , i.e.,  $D \in [(1-\varepsilon)D, (1+\varepsilon)D]$ ; where,  $0 \leq \varepsilon < 1$  (Wen and Shu-Hua, 2006). the principal-expected income  $E_v$  and the agent-expected income  $E_u$  in the new contract motivation model can be expressed by:

$$\begin{aligned}
 Ev &= \int_{(1-\varepsilon)D}^{(1+\varepsilon)D} [D - I] \frac{1}{(1+\varepsilon)D - (1-\varepsilon)D} dx \\
 &= D - q(C - D) - \frac{2DF - F^2k}{D} p
 \end{aligned} \tag{2}$$

where,  $k = \frac{1}{2\varepsilon} \ln \frac{1+\varepsilon}{1-\varepsilon}$  and:

$$\begin{aligned}
 Eu &= \int_{(1-\varepsilon)D}^{(1+\varepsilon)D} [I\omega - L] \frac{1}{(1+\varepsilon)D - (1-\varepsilon)D} dx \\
 &= \omega q(C - D) + \frac{2DF - F^2k}{D} \omega p - L
 \end{aligned} \tag{3}$$

To function, the motivation model must satisfy that, the greater the  $D$ , the higher the incomes of the principal and the agent; and when the saved amount relative of the agent self-quoted cost,  $F$ , is closer to the actual  $D$ , the agent income becomes higher. To better analyze the agent behavior and adverse selection problem with this motivation mechanism being used in case of information asymmetry, we incorporated the motivation model into the standard principal-agent model proposed by Mirrlees (1999) and Holmstrom (1979) and built the following optimized model:

$$\max Ev = D - q(C - D) - \frac{2DF - F^2k}{D} p \tag{4}$$

$$\text{s.t. (IR) } Eu = \omega q(C - D) + \frac{2DF - F^2k}{D} \omega p - L \geq \bar{u} \tag{5}$$

$$\text{(IC) } F = \text{argmax}(Eu) \tag{6}$$

and

$$\frac{\partial Eu}{\partial D} > 0 \tag{7}$$

where,  $\bar{u}$  is the agent-retained income level; an agent will not accept the contract if the agent-expected income is less than  $\bar{u}$ . Eq. 6 expresses the  $F$  and  $q$  values at maximal  $Eu$  when (4) and (5) are satisfied.

While tendering or negotiating, the principal encounters a problem as to how to select  $C$  and  $p$  so that the agent self-quoted saved amount  $F$  is within the range of the principal estimated saved amount of project cost, that the actual saved cost  $D$  can be as low as possible and that high-level agents can be attracted to attend bidding; and the agent encountered problem is how to select  $F$  and  $q$  so that its expected income reaches its maximum.

### ANALYZING AND SOLVING

In case of information asymmetry, the principal cannot observe whether or not the agent's quotation  $B$  is consistent with the actual project cost; from (7), we have:

$$\frac{\partial Eu}{\partial F} = 2\omega p - \frac{2kF}{D} \omega p \tag{8}$$

$$\frac{\partial^2 Eu}{\partial F^2} = -\frac{2k}{D} \omega p < 0 \tag{9}$$

$$\frac{\partial Eu}{\partial D} = -\omega q + \frac{kF^2}{D^2} \omega p \tag{10}$$

$$\frac{\partial^2 Eu}{\partial D^2} = -\frac{kF^2}{D^3} \omega p < 0 \tag{11}$$

According to (8) and (9),  $Eu$  is maximum when (8) is equal to zero, thus it follows that:

$$F = \frac{1}{k} D = 2\varepsilon D (\ln \frac{1+\varepsilon}{1-\varepsilon})^{-1} \tag{12}$$

Through mathematical proof, it can be proved that  $D < D/k < (1+\varepsilon)D$ , hence  $F \in [(1-\varepsilon)D, (1+\varepsilon)D]$ , this indicates that in this motivation model, the agent will quote in the range of its estimated project cost to maximize its expected income, but the quotation will be slightly lower than the average estimate cost and that the greater the  $\varepsilon$ , the more different the quotation is from the average. A plot of  $1/k$  versus  $\varepsilon$  value below 20% is shown in Fig. 1:

Figure 1 shows that, the greater the  $\varepsilon$  value, the smaller the  $1/k$  and when  $\varepsilon$  is 20%, i.e., the agent's estimation range of saved cost ( $D$ ) is  $[0.8D, 1.2D]$ ,  $1/k = 98.65\%$ , in other words, the agent's quotation is  $F = 0.9865D$  to maximize the agent-expected income and it is merely 1.35% lower than  $D$ . Normally, the agent's estimation level should be within 10% and thus the relative difference between  $F$  and  $D$  is within 0.3%, that is,  $F$  and  $D$  are barely different. Therefore, it can be inferred that the agent will bid at the estimated project cost in this motivation model.

It's known from (10) and (11) that,  $Eu$  is maximal when (10) equals to zero; according to  $F = D/K$ , it follows that:

$$q = \frac{1}{k} p \tag{13}$$

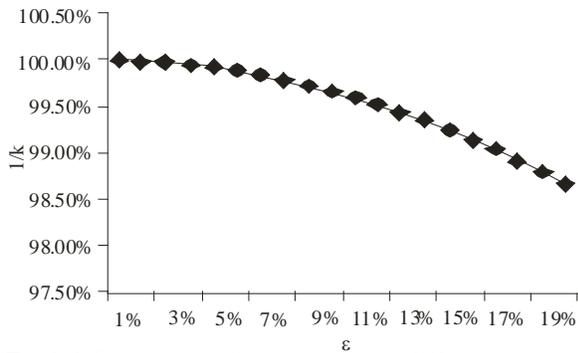


Fig. 1: Influence plot of ε value change on 1/K

From perspective of the agent, the expected income can reach its maximum as long as  $F=D/K$ ,  $q=p/k$ . If so, the agent can quote a higher  $B$  (that is,  $F$  decreases) and then intentionally increase  $A$  in agency work (that is,  $D$  decreases) so as to get more income. Therefore, (7) has to be satisfied and only when the agent-expected income is an increasing function of  $D$ , can the agent make the actual project cost  $A$  as smaller as possible (that is,  $D$  increases). From (10) and (12), we have>:

$$P > kq \tag{14}$$

Based on the previous analysis, when the variation range of the agent estimated project cost is within 10%,  $k \approx 1$ , in other words, to let the motivation mechanism take effect, the deduction percentage  $p$  shall be greater than the agent’s agency rate. This indicates that, in case of information symmetry, a principal can simply pay the agency expense  $qA$  to the agent based on the actually-observed project cost  $A$ . Nevertheless, in case of information asymmetry, it is very difficult for a common principal to know the actual project cost because of the complexity and one-piece nature of an engineering project; therefore, a Pareto Optimality cannot be achieved and the principal can only induce the agent to select the principal-expected actions by means of incentive contract, of which one is that the agent will truly report the project cost and the other is that the agent will try to lower the project cost in agency work, so as to reduce the negative effect arising from adverse selection. Certainly, the principal also needs to pay more expense to the agent than in the case of information symmetry.

When signing an agent contract, the principal has a strong initiative and just needs to pay the agent an retained income level  $\bar{u}$ , that is, (5) is modified such that its left side is equal to  $\bar{u}$ , thus we have:

$$q(C - D) + \frac{2DF - F^2 k}{D} p = \frac{L + \bar{u}}{\omega} \tag{15}$$

Substituting (15) into (4), we have:

$$\text{Max } E_{v=D} = \frac{L + \bar{u}}{\omega} \tag{16}$$

From (16), we can derive that  $\partial v / \partial D = 1 > 0$ , which indicates that, when an agent increases  $D$  as more as possible, the principal-expected income will increase, too. With reference to the above analysis of motivation mechanism optimization problem, it follows that:

$$F^* = \frac{1}{k} D; P^* > \frac{1}{k} q \tag{17}$$

As can be inferred from the above formula, only if the principal sets a proper deduction percentage  $p$ , the agent will automatically quote a project cost  $B$  (i.e.,  $F$ ) and let  $B$  equal to the actual project cost  $A$ , furthermore the agent will try to lower the actual project cost in agency work. When the agent is a design institute, a supervision agency or a project cost consultation company, the agency rate  $q$  will be much less than 1; at this moment, it is quite probable for the principal to make  $p > q/k$  hold so that the motivation mechanism can function well. If the agent is the builder, then the agency rate  $q = 1$ , in other words, all the cost the builder saves is its own income; it is impossible that the deduction percentage  $p$  is greater than 1, in other words, the prerequisite of the motivation mechanism cannot hold.

When the agent is the builder and twice pricing method is adopted, although the expense can be lowered through multiple-party price competition in tendering and review in settlement, the project cost excessively and falsely reported by the builder will fully become the income of the builder, let alone “shared profit” with the principal; therefore, the motivation mechanism fails to function and other commission strategy shall be adopted instead.

When the information is asymmetric, if the principal-agent relationship is multi-time rather than one-time, then “time” itself will probably solve the agency problem even without an incentive contract, as if repeated gambling may solve the prisoner’s dilemma (Hou and Li, 2002). Intuitively, in a long-term relationship, exogenous uncertainties can be eliminated according to a majority of theorems on one hand (Phelan, 1998); and on the other hand, a principal can also enhance information observation and identification from frequent commissions and infer the actual project cost so that the information tends to be symmetric. Moreover, the “Prestige Model” was employed to demonstrate that long-term agency cooperation helps solve the adverse selection problem (Wei-Ying, 1997). For traditional agents participating in bidding, the expected income is  $E_u = \omega q B - L$ ; suppose that an agent

experiences  $n/\omega$  agent bids for different principals in  $t$  years and gets  $n$  times of agency work and the average agency fee paid by the principals is  $I_1$ , then the agent-expected annual income  $W_1 = n(I_1/\omega)/t$ . If the principals adopt long-term cooperation relationship with the agent and the agent is able to carry out  $m$  ( $m>n$ ) times of agency work in  $t$  years, then the agent-expected annual income  $W_2 = mI_2/t$ . If the agent-expected annual incomes are the same, i.e.,  $W_1 = W_2$ , then it follows that:

$$I_2 = \frac{n}{m} (I_1 - \frac{L}{\omega}) = \eta (I_1 - \frac{L}{\omega}) \quad (18)$$

where,

$\eta$  = The intermittent rate of agent work and  $\eta = n/m < 1$

It can be known from (18) that, if the principal and the agent adopt a long-term cooperation relationship, then the agency expense paid by the principal,  $I_2$ , will be less than the agency expense for non-long-term strategic cooperation (Mohr and Spekman, 1994),  $I_1$ . When the agency market competition is fierce and the principal has high selectivity,  $\eta$  and  $\omega$  will be smaller and the agency expense will be less compared with  $I_1$ ; the more the agent bidding expense, the higher the  $L$ . If no intermittent management and bidding expense will occur when cooperation relationship is adopted, the agency expense will also become less. It follows from (16) that  $\partial Ev/\partial L = -1/\omega < 0$ , which indicates that the principal income is a decreasing function of bidding expense  $L$  and that the more the agent's bidding expense, the smaller the principal income. In addition, it

follows from (16) that  $\partial Ev/\partial \omega = L/\omega^2 < 0$ , which indicates that, the principal income is an increasing function of bid-winning rate; if it is long-term cooperation, then  $\omega$  is equal to 1 and the principal income is far more than the tendering income. In summary, long-term strategic cooperation aids in solving the problem of adverse selection and in reducing agency expense; in particular when the agent is the builder, a motivation mechanism is hard to function, then it is preferred to adopt a long-term cooperation strategy for agent selection as much as possible.

### CALCULATION EXAMPLE

Suppose that a designer bids for a project, the owner believes after estimation that the project expense is about 30 million RMB Yuan and finds that the design rate  $q$  is 2%, so the owner initiates a tender with 30 million RMB Yuan as the price ceiling and 3% as the deduction percentage for design  $p$ , the designer quotes the project cost  $B$  after design and the design expense is calculated with (1) in settlement based on the project construction contract price  $A$ . Suppose that a designer has two bidding proposals, i.e.:

**Proposal 1:** A general design team is arranged for design bidding, with the estimated project expense after design being about 27 million RMB Yuan, the design cost rate being about 1% of project cost and the bid-winning rate being 50%

**Proposal 2:** A well-experienced design team is arranged for design bidding, with the estimated design project

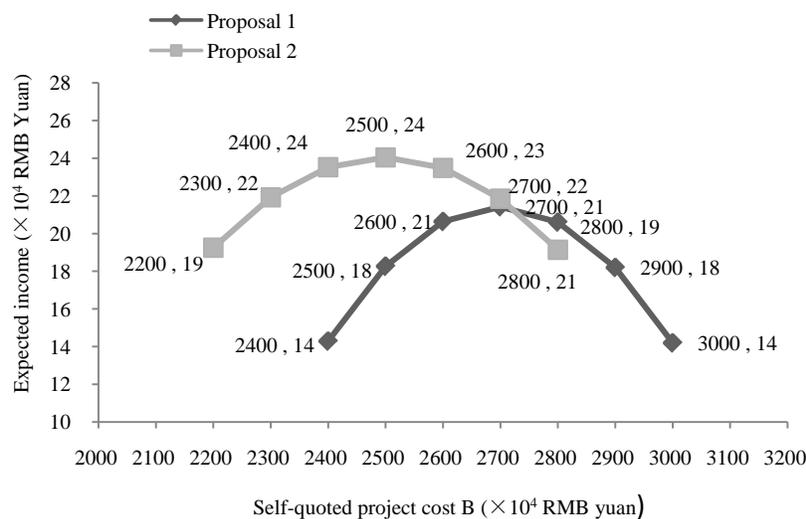


Fig. 2: Comparison of expected incomes in different proposals

expense being about 25 million RMB Yuan, the design cost rate being about 1.3% of project cost and the bid-winning rate being 70%. The bidding expense of either proposal is 20,000 RMB Yuan and the estimation accuracy of project cost is 10%. To study the influences of different self-quoted project costs ( $B$ ) on the expected design fee  $E_u$ , the designer changed the self-quoted  $B$  values in an increment of one million RMB Yuan and calculated the expected incomes for self-quoted values in different proposals (Fig. 2):

It can be known from Fig. 2 that, whichever the proposal may be, if only the self-quoted project cost is consistent with the estimated actual value, then the design fee income of this proposal will be the highest. In Proposal 1, 27 million RMB Yuan is quoted and the maximum expected income is 210,000 RMB Yuan; in Proposal 2, 25 million RMB Yuan is quoted and the maximum expected income is 240,000 RMB Yuan. Therefore it is evident that, a designer must "tell the truth" and then can obtain the maximum expected income. The income line of Proposal 2 is above that of Proposal 1, indicating that the income of Proposal 2 is more than that of Proposal 1. The agent will adopt Proposal 2 given by the well-experienced design team to get better income and this indicates that the motivation mechanism aids in attracting more superior agents to bid, so the principal can select a better agent. The income line of Proposal 2 is on the left of that of Proposal 1 and this indicates that the higher level the bidding agent has, the lower the self-quoted project cost, which helps the principal select higher-level agent among numerous bidders. This calculation example shows that the motivation mechanism in this study can efficiently motivate the agents to tell the truth and help the principal select a higher-level agent.

## CONCLUSION

Traditional project agency expense is generally calculated at a rate of the cost of the commissioned project, for example, the China national charging standards for design fee and project cost consultation fee are based on the rates of project cost, which is not only detrimental for the agent to lower the agency fee initiatively but also detrimental to project cost control. Even if the agent contract adopts a lump sum price and the agency fee is irrelative of project cost, the agent has no impetus of lowering project cost because the project cost is irrelative of the agent income. Accordingly, this study presents a new motivation mechanism to motivate the agent to expose hidden information automatically

when signing the contract and to induce the agent to select the principal-expected actions so as to create more value; it is also pointed out that, if the agent is the builder, then it is not suitable to adopt the motivation method, instead, the manner of long-term strategic cooperation is recommended.

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