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## **An Analysis of the Collusive Game and Governance Strategy between the Supervisor and the Contractor under the Asymmetric Information**

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**Abstract:** Project contract is the incomplete contract and the rights and obligations between the parties of the contract cannot be accurately determined because of the inherent characteristics of asymmetric information, incompleteness, the parties' bounded rationality and each party in pursuit of maximizing their own interests. This gives rise to the collusive risk of the project in the process of construction between the supervisor and the contractor. This study firstly takes the supervisor and contractor as each party of the game by using the view of game theory and establishes the game model based on the theory of asymmetric information and then analyzes the effective treatment for both parties' gambling behaviors, finally discuss the governance strategy on the prevention of the collusion between the supervisor and constructor.

**Key words:** Information asymmetry, contractor, supervisor, construction market, game model

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### **INTRODUCTION**

A construction market has three main bodies, the owner, the contractor and the supervisor. In order to guarantee the smooth completion of the project, the owner usually entrusts the supervisor with exercising the supervisory power in place of them. In the construction process of the project, the supervisor supervises the constructor openly, justly, fairly which not only is the important safeguard for ensuring that the project reaches the quality standard stipulated by the construction contract as well as laws and regulations concerned but also is the effective guarantee for controlling the project cost.

However, there are still some problems on the implementary effect of the supervision. The project contract is the incomplete contract and the rights and obligations between the parties of the contract cannot be accurately determined, because of the inherent characteristics of asymmetric information, incompleteness, the parties' bounded rationality and each party in pursuit of maximizing their own interests. In addition, the supervisor's lower pay from the owners make the collusive risk exist between the supervisor and the contractor in the project construction process. The phenomenon of the collusion not only brings huge loss to the owner, but also threatens the project's quality and each participant's long-term interests. In order to maintain the order of construction market, governing collusive behaviors between the supervisor and the contractor effectively is imperative.

In order to avoid hurting the interest of the owner resulted from the supervisor and the contractor making use of their own information advantage to obtain greater profits under the condition of asymmetric information, this study first takes the supervisor and the contractor unit as each side of the game by using the view of game theory and establishes the game theory model based on the theory of asymmetric information, then analyze the effective treatment for both the gambling behaviors and finally discuss the governance strategy on the prevention of the collusion between the supervisor and the constructor.

### **ENGINEERING PROJECT RISK BASED ON THE THEORY OF THE ASYMMETRIC INFORMATION**

**Major participants' diagram in the project construction process:** As is known, the whole life cycle of the project includes the decision-making process, the construction process and the using process. The construction process is the process of forming construction products and has very strong asymmetry of information. The information asymmetry exists mainly in two aspects, one including the bidding process; the other including construction process.

In the process of forming building products, there are five subjects, namely the construction administrative department, the owner, the contractor, the supervisor and the equipment (material) supplier and the relationship between them is as shown in Fig. 1.

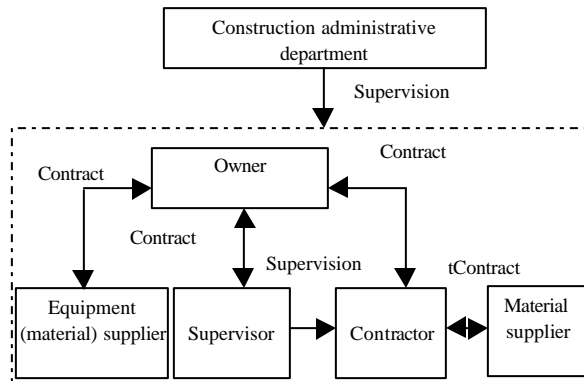


Fig. 1: Major participant's diagram in the project construction process

In the five parties, the construction administrative department mainly plays a supervising role, so it is not the complete party in the market. So, this study does not list it as an effective participant in the asymmetric information.

**Classification of the information asymmetry in the project construction process:** Information asymmetry is the distribution of knowledge or probability about certain events distributed asymmetrically among the corresponding economic persons. The asymmetric theory is the important content of microeconomics which can be used to handle the impacts and the resulting market operation efficiency in the information market brought by related information being distributed differently to transaction parties. The asymmetric distribution of information is suitable in any main market body, the construction market being no exception. The information asymmetry is mainly divided into the following categories in the project construction process:

- Information asymmetry between the owner and the contractor:** The information asymmetry between the owner and the contractor mainly has the following two processes. In the bidding process, the contractor may deliberately hide their private information and provide false information to the owner, thereby obtaining the advantageous position in the contract which easily cause the problem of adverse selection. In the construction process, namely after both sides signing a contract, if the building unit doesn't implement the effective supervision of behaviors of the contractor, the real behavior information can't be obtained from the owner. If the relevant incentive and restraint mechanism is not perfect, the contractor may use their own advantages of information resources

and take the behavior benefiting themselves. Thus the interest of the owner will be damaged, thereby resulting in the risk of moral hazard

- Information asymmetry between the owner and the supervisor:** The information asymmetry between the owner and the supervisor also mainly exists in the process of bidding and construction process. In the bidding process, the problem of adverse selection is easily to be caused. In the construction process, due to the supervision mechanism, the power of the owner's supervision is empty. As a result, the supervisor probably hurt the interest of the contractor by using the advantage of their own information resources, thereby generating the problem of moral risk
- Information asymmetry between the owner (the contractor) and the supplier:** If the materials and equipment are provided by the owner agreed in the contract, the problems of adverse selection and moral hazard also exist because of the asymmetric information between the owner and the materials (equipment) supplier. If the contract agrees that the owner only provide the equipment and the contractor is responsible for the procurement of materials, the problems of adverse selection and moral hazard also exist brought by the asymmetric information between the owner and the equipment supplier and between the contractor and the materials supplier
- Information asymmetry between the supervisor and the contractor:** The information between the supervisor and the contractor is also asymmetric from the angle of information economics. In the construction market, the supervisor as the agent of the owner, the relationship between the supervisor and the contractor is supervising and being supervised. In general, the supervisor is familiar with the construction of the building products, but they don't know enough such information as to management, technology, capacity, the degree of subjective effort and the contractor whether to choose the action in conformity with the owner's goal. Consequently, the problem of the information asymmetry exists between both sides because of incomplete information (Ye *et al.*, 2011)

**Risk of collusion based on the theory of information asymmetry:** In Shannon's information theory, information is used to eliminate some uncertainty. If the information is increased, the uncertainty can be reduced and the risk will be decreased accordingly. In extreme cases, when people get the complete information, the risk does not exist; when people are in the blind information state, the risk of economic behavior is the greatest.

Generally speaking, in the project construction process, the risk under the condition of symmetric information or asymmetric information has the essential distinction. Under the condition of symmetric information, the risk is usually the one of objective events such as natural risk, political risk etc. The distribution of the information between the project participants is equal, so each participant's level of the risk is same. Under the condition of asymmetric information, the risk usually arises from each participant's decision behavior. Due to the asymmetry of the information in the construction market, the information is not judged by the project participants who often cause the behind-the-scenes plot in the construction market. Moral hazard may arise because of the information asymmetry among the owner, the supervisor and the contractor, i.e. the supervisor will act in collusion with the contractor and thus harm the economic interest of the owner. by using the advantage of their own information for the sake of their own economic interests. The following are the main reasons resulted in the asymmetry information (Ma, 2008);

- **Communication about information is in lack and poor:** Currently, due to the wide range of application of the network technology in the field of the project, the construction administrative department, the owner, the contractor, the supervisor etc. all establish the database in different aspects and a large quantity of engineering information is released immediately through the Internet. But the problem existing in China is the lack and poor communication of the information occurring from the problems of the information exchange and the system integration between different units remaining unsolved
- **System of laws and regulations is not perfect and information disclosure is in the lack of security system:** At present, the legal framework which adapts to the continuous development and updating of building market is not perfect and information disclosure is in the lack of security system. Due to the lack of complete laws and regulations to regulate the information disclosure of the whole society, the collection and disclosure of the information about breaking faith is not enough.
- **Strength of constraints and punishments is insufficient and the cost of breaking faith is low:** The insufficient strength of constraints and punishments for the various types of non-standard behaviors in the construction market and the low cost of breaking faith are the basic reasons for causing the collusive behaviors between the supervisor and the contractor. Once the income of

breaking faith is greater than the cost of breaking faith, the phenomenon of the collusion may be more and more widespread (Zhang and Li, 2002)

### **GAME MODEL OF THE COLLUSION BETWEEN THE SUPERVISOR AND THE CONTRACTOR UNDER THE ASYMMETRIC INFORMATION**

**Basic theory of the game:** The game theory refers to the process during which a person or an organization, in the face of certain environmental conditions, according to certain rules, select and implement their respective selected behaviors or strategies and obtain the corresponding results or yields from the respective, depending on the available information. It is a very important theoretical concept in economics.

There are many examples of the application of the game theory in the reality. Almost all problems in our life can be explained by using the game theory. The game theory can also be applied to the implementation process of the project. The rational players(the participants) choose their strategies and balance them (the final results of the project management) in order to maximize their own interests. This game includes the vital factors constituting the game theory. The factors are participants (each subject in the project), action (the project management of each party), information, strategy (taken and to be taken for maximizing benefits by each party), payment, results and equilibrium.

The game can be divided into cooperative and non-cooperative ones. The difference of the cooperative and non-cooperative games lies in that whether parties could reach an agreement or not, when the behaviors of the parties are interacted. If they could, it is a cooperative game, otherwise, a non-cooperative one. The non-cooperative games can also be divided from the following two perspectives:

- The first perspective is from the time which involves the sequence of the actions. From this perspective, the game theory can be divided into static and dynamic games. The static game is that participants choose actions at the same time or not at the same time but the after actors do not know specific actions chosen by the first actors. The dynamic game refers to that the participant's actions have the sequence and the after actors can observe the actions chosen by the first actors
- The second perspective is from the information, namely according to the classified knowledge about the other participants' characteristics, strategy and the function of the benefits. From this perspective,

the game can be divided into complete information game and incomplete information game. Complete information means that each participant can accurately understand all other participants' characteristics, strategy space and the function of the profit; otherwise it is the incomplete information

- If the two perspectives are combined, we could obtain four different types of non cooperative games: static game of the complete information, dynamic game of the complete information, static game of the incomplete information, dynamic game of the incomplete information. They are corresponding to the following four equilibriums, respectively: Nash equilibrium, sub-game perfect Nash equilibrium, Bayesian Nash equilibrium, perfect Bayesian Nash equilibrium (Yan, 2010), as shown in Table 1

**Game model of collusion between the supervisor and the contractor under the asymmetric information:** In the project construction process, the supervisor does not know the situation about the authenticity and legality of the contractor's information. That is to say, the information between each other is asymmetric. According to the view of dynamic game, namely the refined theory of Nash equilibrium, it assumes that the supervisor and the contractor are all rational, then the contractor's behavior is first and the supervisor's is after. In fact, this is the process of dynamic game between them:

- **Cases of asymmetric information probably occurring:** In the process of the project achieving a goal, the following four kinds of circumstances may appear because of asymmetric information:

Firstly, the contractor doesn't breach the contract and the supervisor and the owner have the same goals. In this case, the supervisor and the contractor fulfill responsibilities under the contract, respectively and achieve the goal of the project. Except for the majeure appearing, the probability for the realization of the owner's target is very large.

Secondly, the contractor doesn't breach the contract and the targets of the supervisor and the contractor are inconsistent. If the contractor performs the contract rightly, whether the supervisor carries out the supervision will almost not affect the realization of the project goals and in this case, the supervisor has the moral risk.

Thirdly, the contractor breaches the contract and the goals of the supervisor and the owner are consistent. The supervisor judges the illegal actions of the contractor and reveals the illegal actions of the contractor. If the contractor doesn't choose the action of being consistent with the target of the owner, despite the supervision done by the supervisor, the project's objectives also may not be gained.

Fourthly, the contractor breaches the contract and the goals of the supervisor and the owner are inconsistent. The supervisor judges the illegal actions of the contractor and has the evidences. Once the rent-seeking of the contractor is successful, the supervisor will be collusive with the contractor and doesn't reveal the illegal actions of the contractor. In this case, the project's target is not gained generally.

In the above four circumstances, the collusion will never exist in the first and the second case and not exist for a while in the third case. But even if the supervisor subjectively did not breach the intention of the owner and if the contractor will be collusive and agree to pay the incomes of the collusion, it also may be reversed into the fourth case once the incomes of the collusion is greater than the cost of the punishment (Liu, 2012).

- **Hypothesis of game model under the asymmetric information:** Firstly, the game between the contractor and the supervisor is non cooperative game

Secondly, the contractor and the supervisor are rational people which seek to maximize their utility;

Thirdly, the supervising engineer which implement the specific supervising task obeys the orders of the supervisor and is consistent with the interests of the supervisor;

Fourthly, the owner inspects the project continuously in the construction process and will punish the illegal behavior once finding any.

In the project construction process, the supervisor and the contractor choose their decisions according to each other's decision. If one party only knows the other's distribution of probability and don't know its true type, it is not possible to accurately know what strategy the other party will actually choose, but it can correctly predict how the other party's choice depends on their respective types. Then this decision goal is changed into the following: Under the condition of the given own types

Table 1: Game classification

Classification of Information	Static information	Dynamic information
Complete information	Complete information	Complete information
(Static game "Nash equilibrium")	Complete information	(static game "Nash equilibrium")

and compliant strategies of the other's type, it is to achieve the maximization of their expected utility (Sha *et al.*, 2004). The probability distribution of both the supervisor and the contractor choosing their strategy is as shown in Table 2.

As you can see from Table 2, their joint probability distribution is (0, 0) because the (no collusion, collusion) and (collusion, no collusion) are exclusive events.

- Analysis of the collusion game model between the supervisor and the contractor:** The collusion game model between the supervisor and the contractor is shown in Table 3. The two expressions in each space represent the expected returns of the supervisor and the contractor under the corresponding strategies. Their joint probability is 0 because the (No collusion, collusion) and (collusion, no collusion) are exclusive events. Therefore, the expected returns of the supervisor and the contractor are the price of the contract

The meaning which the characters represent in the formula is:

- m = Grey cost which the contractor pay to the supervisor when they are in collusion
- G = Benefits are gained by the contractor after the success of the collusion behavior (G is greater than m)
- k = When there are no collusions, the good reputation of the supervisor which is established from fulfilling the obligation of supervision justly brings income now or in the future(That is the income of the credit of the supervisor)
- F = After the supervisor found and prevented irregularities, the losses suffered by the contractor
- h = The collusion was found by the owner, the supervisor's losses

Table 2: Probability distribution of both the supervisor and the contractor choosing their strategy

Probability distribution		Contractor	
		No collusion	Collusion
Supervisor	No collusion	(1-θ, 1-γ)	(0, 0)
	Collusion	(0, 0)	(θ, γ)

Table 3: Expected returns

Expected returns		Contractor	
		No collusion	Collusion
Supervisor	No collusion	αk-(1-α)hβ -αF + (1 - α)[-pβ + G(1 - β)]	A*, B* (1 - θ)(1 - γ)[αk - (1 - α)hβ] + θγ[αk - (1 - α)hβ]
	Collusion	A, B	(1 - θ)(1 - γ)(G - m - pβ) + θγ[-αF + (1 - α)[-pβ + G(1 - β)]

- β = Probability of the supervisor finding the contractor's violating the contract also called detection probability
- α = Probability of the supervisor finding and exposing illegal manipulation of the contractor (the probability is an increasing function of the degree of the owner's supervision, namely when α is very small, even the supervisor finds the contractor's illegality, the supervisor may also not expose this because of their own interests)
- p = When the owner found the contractor's illegality, this is the punishment which the contractor meet

We can see from Table 3:

- Function of the supervisor's expected income:

$$M = (1 - \theta)(1 - \gamma)(m - h\beta) + \theta\gamma[\alpha k - (1 - \alpha)h\beta] \quad (1)$$

Making the differentiation for the utility function and then it could get the supervisor's optimized first-order conditions that is:

$$\frac{\partial M}{\partial \theta} = \gamma[m + \alpha k + \alpha h\beta - 2h\beta] - m + h\beta = 0 \quad (2)$$

We can draw:

$$\gamma^* = \frac{m - h\beta}{\alpha k + (\alpha - 2)h\beta + m} \quad (3)$$

- Function of the contractor's expected profit is:

$$N = (1 - \theta)(1 - \gamma)(G - m - p\beta) + \theta\gamma[-\alpha F + (1 - \alpha)[-p\beta + G(1 - \beta)]] \quad (4)$$

Differentiating the utility function above, it will gain the contractor's optimized first-order conditions that is:

$$\frac{\partial N}{\partial \gamma} = \theta[-\alpha F - m + (\alpha - 1)G\beta + (2 - \alpha)G + (\alpha - 2)p\beta] - G + m + p\beta = 0 \quad (5)$$

We can draw:

$$\theta^* = \frac{G - m - p\beta}{-\alpha F - m + (\alpha - 1)G\beta + (2 - \alpha)G + (\alpha - 2)p\beta} \quad (6)$$

Namely, "Nash equilibrium solution" of mixed strategy of the static game under the non-cooperative incomplete information is:

$$\gamma^* = \frac{m - h\beta}{\alpha k + (\alpha - 2)h\beta + m} \quad (7)$$

$$\theta^* = \frac{G - m - p\beta}{-\alpha F - m + (\alpha - 1)G\beta + (2 - \alpha)G + (\alpha - 2)p\beta} \quad (8)$$

Because  $\gamma^*$  and  $\theta^*$  are probability value, they must meet the following conditions:  $0 < \gamma^*, \theta^* < 1$ .

When we would gain the solution for Nash equilibrium of the mixed strategy, the conditions of the solution's existence are:

$$-0.5\alpha h\beta + 1.5h\beta - \alpha < m \quad (9)$$

$$(\alpha + \beta - \alpha\beta - 1)G < (\alpha - 1)p\beta - \alpha F \quad (10)$$

In the functions:

- Equation 7 expresses that the contractor don't choose the collusion with the probability of  $\gamma^*$ , it can also be interpreted that the contractor don't choose the collusion with the proportion of  $\gamma^*$
- Equation 8 expresses that the supervisor chooses the collusion with the probability of  $\theta^*$ , it can also be interpreted that the supervision unit choose the collusion with the proportion of  $\theta^*$

Because in this model there are two choices of joint probability strategy mutually exclusive, i.e., the probability distribution is (0, 0) which has been described previously, Nash equilibrium of comprehensive strategy could be realized only when both the  $\gamma^*$  and  $\theta^*$  have solutions. That is to say, only when the Eq. 9 and 10 are formed at the same time, Nash equilibrium solution of mixed strategy could exist.

If the Eq. 9 and 10 aren't formed at the same time, Nash equilibrium solution of mixed strategy couldn't exist. That is, the state of the "Nash equilibrium" which would be achieved doesn't exist with probability of no zero by the (no collusion, no collusion). In the Eq. 9,  $h\beta$  means the expected value of the supervisor's loss, when the collusion is found by the owner and  $m$  is the gray cost

which is paid by the contractor to the supervisor. According to the rational assumption, the equation of  $-0.5\alpha h\beta + 1.5h\beta - \alpha < m$  may be set up.

However, in the Eq. 9, in the present stage, the general situation of our country is: the probability of the supervisor finding and exposing the contractor's illegal behavior is  $\alpha$  and the probability of the owner finding the contractor's collusive behavior is  $\hat{\alpha}$  which is small, but once the contractor selecting the collusive benefits  $G$  is greater than the gray costs  $m$  of being paid to the supervisor and the degree  $p$  of the contractor's punishment is not big enough after  $t$  the owner finding the illegal behavior. So, according to the results of the existing analysis and the principle of income's maximization, in China's current system, the selection of collusion made by the supervisor and the contractor is the rational choice.

Therefore, the game result between the supervisor and the contractor will be in the deadlock of "collusion, collusion" according to the hypothesis of rational man. The way to break the ice is to make the Eq. 9 and 10 be met at the same time, mixed strategy "Nash equilibrium" exists.

**Theory description of the game results:** If the owner and the construction administrative departments can't monitor the contractor and supervisor effectively, there will be moral hazard between the contractor and the supervisor in the state of informational disadvantage. At present, however, based on the analytical results of the game model, if the supervisor grasped the illegal evidence concerning the contractor, the strategy which the rational supervisor selected is not reveal but collusion and the rational strategy chosen by both sides is collusion.

Because of the incompleteness of information, according to the hypothesis of signal transmission model in information economics, there are both honest and dishonest supervisors in the construction industry. As a result of information asymmetry, it will greatly increase the chances of collusion when the owner takes adverse selection for the sake of interests and chooses dishonest supervisor and contractor in the project construction process. Hence, such phenomenon will come into existence in China's construction markets: the contractor and the supervisor following rules and regulations will become fewer and fewer while those violating rules and regulations more and more. The number of honest units will become smaller and smaller while that of dishonest units larger and larger.

**Governance strategy:** In order to regulate the construction market, it is a top priority to enhance the

public confidence in the engineering quality and strengthen the governance of the collusion between the supervisor and the contractor. Overall, a series of comprehensive supporting measures are needed to treat the problem of collusion. These specific measures are shown as follows:

- Firstly, from the perspective of supervision, the regulatory rules and regulations must be improved and perfected and the monitoring responsibility be strengthened by strengthening the supervision role of the construction administrative departments and the owner. Once the phenomenon of conspiracy is found, the power of punishment should be increased
- Secondly, from the perspective of the owner, it is necessary to improve the relevant arrangement of governance structure, especially about the system in the supervisor and the contractor, to reduce the phenomenon which bad money drives out good
- Thirdly, from the perspective of the supervisor, the improvement on the internal governance must be made, the awareness of risk enhanced in practice and the regulatory quality improved
- Fourthly, from the perspective of practice standard, the behavioral standard of the contractor and the supervisor must be further improved and the information disclosure more comprehensive and specific in the requirements which reduces the operating space of information disclosure
- Fifthly, from the perspective of the external environment of the building market, it is necessary to increase the punishment level for illegal acts and of great importance to create a good social atmosphere, establish the social fashion of good faith, perfect the social credit system and increase the social return of good faith

In order to standardize the construction market, break the deadlock of conspiracy, it is necessary to make the construction market honestly run. As mentioned above, the measures should be taken such as strengthening the supervision of supervisory organizations, increasing the punishment of the dishonest supervisor and the contractor 'collusion, establishing the credit system in construction market, increasing the supervisor' integrity income and so on. Nevertheless, in China's current construction markets, the above measures lack realistic operability with the following reasons. First, improving the comprehensive governance is restricted by the existing relevant system and its cost is high. Second, the civil compensation system being imperfect in our country at present, it is not economical to increase the claim for

compensation related to the punishment of dishonest supervisor. Third, the construction of the social credit system in our country lags behind and thus in the short run the substantial increase of integrity benefits from the supervisor may not be realized.

Thus, during the process of waiting for the mature conditions to come and gradually implementing the above governance measures, the more feasible ways at present are shown as below: taking the decisive and feasible measures to strengthen the standard and administration of the construction market, strengthening the examination of the qualification of the supervisor and supervision engineers professional qualification, enforcing the supervision of the supervisor and the contractor, breaking the deadlock of collusion chosen by both of them and urging them to honestly serve the construction market.

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