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Game Analysis of Project General Contracting Rent-seeking

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Abstract: It is important to clearly understand the rent-seeking behavior of all parties involved in the general contracting mode. First, the formation mechanism of rent-seeking was analyzed. Then, the game model of the owners, general contractors, supervision units, government and society during the operation of the general contracting project was proposed，to explore the decision-making space and behavior mechanism of relevant stakeholders. Finally, the optimal decision-making of the game players under different situations was discussed. The results show that the general contractor and supervision rent-seeking probability is affected by the owner's supervision cost and supervision probability; the probability of owner supervision is related to the ability of owner and government public to supervise and punish rent-seeking behavior; and the ability of government and public to supervise is related to the cost of supervision and the reward value of supervision success.

1. Introduction
Project general contracting originated in China in the 1980s.It is a new construction mode that gradually develops and evolves according to market needs in practice. Ma Liang et al.[1] combed the research literature on general contracting of projects, pointing out that project safety management and construction management in the field of general contracting of projects in the future will become a research hotspot. However, in actual process of project management, all parties of construction projects often seek rent to maximize their benefits, which makes safety management of construction projects more difficult.

Relevant domestic scholars have studied rent-seeking behavior from different perspectives.In view of modern economics, Cai Ruxing[2] analyzed bilateral rent-seeking phenomena in bidding and construction of construction projects; Jiang Xuehai[3],studied the rent-seeking behavior of all parties involved in the project from the perspective of safety supervision; Zhang Changzheng et al.[4] established the behavior game model of each subject under different construction projects.The above research has a certain reference significance for understanding the rent-seeking behavior of all parties in the field of engineering projects. However, there are few studies on rent-seeking theory in the field of general contracting, and the construction project can not be studied as a whole. In view of this, according to the particularity of the project general contracting project, this paper under the general contracting mode, attempts to combine the rent-seeking theory with the stakeholder theory, study the rent-seeking behavior in the construction project operation process .

2. In the field of constructionDiscussion on the formation mechanism and behavior of rent-seeking

2.1 Research on the formation mechanism of rent-seeking
The theory of rent-seeking was first proposed in the related research of new institutional economics

theory[5]. Rent-seeking is interpreted as a non-productive activity that redistributes vested interests [6].According to the hypothesis of rational economic man, the individual's decision-making behavior always tends to maximize its own interests. The separation of the owner and the user of power makes the rent-seeking subject have operating space. From the perspective of macroeconomics, the regulation and control of production activities by power owners such as the government will inevitably lead to rent-seeking behavior. The intervention of power owners in economic activities will form decision-making space for activities, so that the benefits of public space are greater than those of normal production[7].In construction engineering field, existing studies generally believe that there are asymmetric information and limited rationality between rent-seeking parties. The confusion of authority and unclear management of relevant management departments contribute to rent-seeking. To avoid rent-seeking behavior, we could start from two parts: supervision mechanism and power department.

2.2 Discussion on rent-seeking under the general contracting mode
In the field of general contracting, most projects are large-scale projects of infrastructure type, in addition to the supervision of the government and other relevant departments, they are often supervised by non-profit departments such as the society and the public. The relevant entities in the whole process of project construction are simplified into four parts: owner, general contractor, supervision unit, government and the society.

In the construction of the project, rent-seeking behavior will cause waste of social resources, hinder the effective operation of market mechanisms, and reduce the credibility of government departments. On the other hand, the supervisory unit as a rational economic person is extremely easy to seek rent from the general contractor, and seeks the best interests to seek collusion and thus endanger the safety of the project. Therefore, starting from the relationship among the relevant subjects of general contracting, this paper studies the right rent-seeking as a whole in the whole process of engineering construction from qualification examination, bidding, design, construction and acceptance of completion.

3. Assumption and Establishment of Rent-seeking Model

3.1 Model Hypothesis
Drawing on the game model proposed by Feng Qun[8], and without considering the acceptable range of rent-seeking in the process of realizing project safety, this paper generalizes the main rent-seeking actors as owners, general contractors, supervision units, government and society. Based on this, the following assumptions are proposed:

(1) The government and society supervise the whole process of the project, the probability is 1.

(2) The government and society include the government safety supervision department, public, media, and various non-profit organizations. All relevant parties are rational people with ethical standards and technical standards. Therefore, there is no deed behavior that colludes with other units.

(3) The owner entrusts the responsibility for project safety supervision to the supervision unit, and its rights are collected as O. O is a collection of rights obtained by the supervision unit during the actual construction process, $o \in O$. The specific performance of o is the supervision of the general contractor's behavior, including the qualification audit of subcontractors, the quality supervision of purchasing equipment and so on. Measured by the actual market value, the expected value of the owner's function in the process of performing the function is V.

(4) When the supervisory unit conducts rent-seeking, the expected value V of o will be lost ΔV. It converted into the income of the supervisory unit itself. When $\Delta V > 0$, the rent-seeking is successful;when $\Delta V = 0$, the rent-seeking is unsuccessful. The probability that the general contractor and the supervisory unit jointly seek rent is P. When the supervisory unit accepts the rent-seeking of the general contractor, it receives the rent $m\Delta V$ from the general contractor, and the income of the

general contractor is $(1-m)\Delta V$, $0<m<1$. The loss of the owner is $K\Delta V$ (K for the loss factor, $K>1$, including economic losses and quantified non-economic losses).

(5) The owner and the society publicly supervise the behavior of the general contractor. If one party supervises successfully, it will impose penalties on rent-seeking. α, S, β are respectively the probability of owner's supervision, the cost of supervision and the probability of success of supervision.The probability of public supervision is 1, the cost of supervision is Y, and the probability of public supervision and success is ε. Once rent-seeking behavior is found, the owner gives reward Z. （$Z<m\Delta V$；$\alpha, \beta, \gamma \subset (0,1]$）

(6) When the rent-seeking behavior of the general contractor and the supervision unit is discovered, the general contractor is fined $n(1-m)\Delta V$; accordingly, the rent-seeking income of the supervisory unit will be confiscated and also subject to the penalty $nm\Delta V$. $(n<1)$

3.2 Dynamic Game Model of Incomplete Information for Main Body of Project General Contracting
Based on the above assumptions, the dynamic game model of incomplete information of each main body of the general contracting project is shown in Figure 1.

As shown in Figure 1, under the general contracting mode, there will be eight kinds of game results in the case of asymmetric information.

(1) When the supervision unit and the general contractor conduct rent-seeking, the owner acts as the main body of decision-making. When the owner chooses to supervise, the possible outcomes are that the non-profit departments and the government supervise are success, the owner's supervision is successful but the government is unsuccessful, the government supervision is successful, the owner's supervision and the government both unsuccessful. When the owner chooses not to supervise, he cannot find the rent-seeking behavior. Under the supervision of the non-profit department, it may or may not find the rent-seeking behavior.
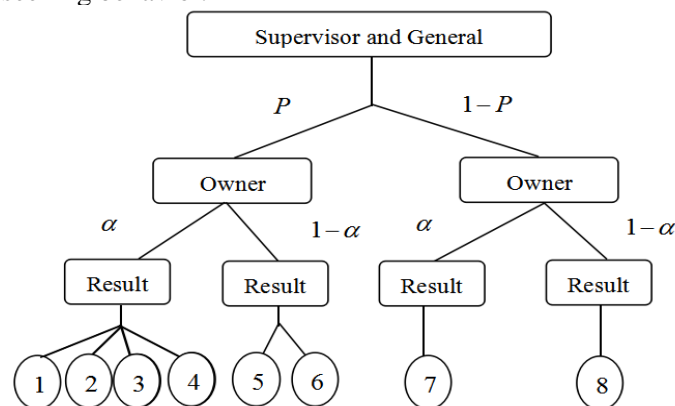

Figure 1. Dynamic Game Model of Incomplete Information for Main Body of Project General Contracting

(2) When the supervising unit and the general contractor do not engage in rent-seeking behavior, the owner also has two choices: supervision or not. When the owners supervise, they will not find rent-seeking behavior. When the owner does not supervise, the rent-seeking behavior not be found.

The benefits of the parties under the game model are shown in Table 1.

Table 1. Income statement of each party under the general contract of the project

No.	Owner	Government and public	Supervisory Unit	General contractor
1	$2n\Delta V-S-Z$	$Z-Y$	$-n（m+1）\Delta V$	$-n（1-m）\Delta V$
2	$2n\Delta V-S$	$-Y$	$-n（m+1）\Delta V$	$-n（1-m）\Delta V$
3	$2n\Delta V-S-Z$	$Z-Y$	$-n（m+1）\Delta V$	$-n（1-m）\Delta V$
4	$-K\Delta V-S-Z$	$-Y$	$m\Delta V$	$(1-m)\Delta V$

5	$2n\Delta V - Z$	$Z - Y$	$-n（m+1）\Delta V$	$-n（1-m）\Delta V$
6	$-K\Delta V$	$-Y$	$m\Delta V$	$(1-m)\Delta V$
7	$-S$	$-Y$	/	/
8	/	$-Y$	/	/

4. Model analysis

Based on the above game model, the inverse inductive method is used to solve the equilibrium solution of the dynamic game model.

(1) The probability of rent-seeking by the supervision unit and the general contractor is P. In the case of certain supervision by the government and the public, the probability of supervision by the owner is α. At this point, the expected return of the owner is as follows:

$$E_1 = P\left\{\alpha\begin{bmatrix} \beta\varepsilon(2n\Delta V - S - Z) + \beta(1-\varepsilon)(2n\Delta V - S) \\ + (1-\beta)\varepsilon(2n\Delta V - S - Z) \\ + (1-\beta)(1-\varepsilon)(-K\Delta V - S - Z) \end{bmatrix} + (1-\alpha)\begin{bmatrix} \varepsilon(2n\Delta V - Z) \\ -(1-\varepsilon)K\Delta V \end{bmatrix}\right\}$$
$$+ (1-P)\{[-\alpha S + (1-\alpha)\times 0]\}$$

For the first-order derivation of the above formula, there is $\dfrac{\partial E_1}{\partial \beta} = 0$, at this time, the best probability P' for the rent-seeking unit and the general contractor to obtain rent is obtained.

$$P' = \frac{S}{(1-\varepsilon)[\beta(2n\Delta V + k\Delta V + Z) - Z]}$$

(2) Given the probability of rent-seeking between the supervisory unit and the general contractor is P, the expected benefits of the government and the public are as follows:

$$E_2 = P\left\{\alpha\begin{bmatrix} \beta\varepsilon(Z - Y) + \beta(1-\varepsilon)(-Y) \\ + (1-\beta)\varepsilon(Z - Y) \\ + (1-\beta)(1-\varepsilon)(-Y) \end{bmatrix} + (1-\alpha)\begin{bmatrix} \varepsilon(Z - Y) + \\ (1-\varepsilon)(-Y) \end{bmatrix}\right\} + (1-P)[\alpha(-Y) + (1-\alpha)(-Y)]$$
$$= PZ\varepsilon - Y$$

When the government and the public have no difference from the income that does not find rent-seeking, there is $E_{21} = E_{22}$, there is

$$E_{21} = P\{\alpha[\beta\varepsilon(Z - Y) + (1-\beta)\varepsilon(Z - Y)] + (1-\alpha)\varepsilon(Z - Y)\}$$

$$E_{22} = P\left\{\alpha\begin{bmatrix} -\beta(1-\varepsilon)Y \\ -(1-\beta)(1-\varepsilon)Y \end{bmatrix} - (1-\alpha)(1-\varepsilon)Y\right\} - (1-P)Y$$

Simplified,

$$\varepsilon' = \frac{Y}{P(2Y - Z)}$$

(3) Given the best probability of owner's supervision α, the expected benefits of the supervisor in the process of game are as follows:

$$E_3 = P\left\{\alpha\begin{bmatrix} -\beta\varepsilon n(m+1)\Delta V - \beta（1-\varepsilon)n(m+1)\Delta V \\ -(1-\beta)\varepsilon n(m+1)\Delta V \\ + (1-\beta)(1-\varepsilon)m\Delta V \end{bmatrix} + (1-\alpha)\begin{bmatrix} -\varepsilon n(m+1)\Delta V \\ + (1-\varepsilon)m\Delta V \end{bmatrix}\right\}$$

Regardless of whether the owner conducts supervision or not, there is no difference in the income of the supervision unit: $\dfrac{\partial E_3}{\partial P} = 0$, then

$$\alpha' = \frac{\varepsilon n(1+m) - m(1-\varepsilon)}{\beta(1-\varepsilon)(nm + n + m)}$$

(4) Given the optimal probability of supervising the owner is α, the expected revenue of the general contractor in the game process is as follows:

$$E_4 = P\left\{\alpha\begin{bmatrix}-\beta\varepsilon n(1-m)\Delta V - \beta(1-\varepsilon)n(1-m)\Delta V \\ -(1-\beta)\varepsilon n(1-m)\Delta V \\ +(1-\beta)(1-\varepsilon)(1-m)\Delta V\end{bmatrix} + (1-\alpha)\begin{bmatrix}-\varepsilon n(1-m)\Delta V \\ +(1-\varepsilon)(1-m)\Delta V\end{bmatrix}\right\}$$

When there is no difference in the return of the general contractor, there is $\frac{\partial E_4}{\partial P}=0$,then

$$\alpha'' = \frac{\varepsilon(n+1)-1}{\beta(\varepsilon-1)(n+1)}$$

5. Game Analysis and Rent-seeking Governance

(1) From the perspective of the owner, the best choice of each subject under the equilibrium game is analyzed. When the benefit of the supervision unit is maximized, the owner's supervision probability to the supervision unit is $\alpha > \alpha'$. At this point, the best decision of the supervisory unit is to give up rent-seeking;When $\alpha = \alpha'$, the supervising unit can choose randomly; if $\alpha < \alpha'$, the supervising unit must choose rent-seeking when considering its own interests.Similarly, considering the maximum benefit of the general contractor, when the probability of owner's supervision over the general contractor is $\alpha > \alpha''$, the optimal decision of the general contractor is not rent-seeking; when $\alpha < \alpha''$, the general contractor chooses rent-seeking instead of pursuing the maximum benefit.

It can be seen that when the benefit of supervision unit is maximized, under the condition that the rent-seeking probability of supervision unit and general contractor is P, the optimal probability of owner's supervision α',which is positively correlated with the probability of successful supervision of the government and the public ε, the penalty multiple n, and the distribution coefficient m, and is negatively correlated with the probability β of the owner's supervision success.The agreed coefficient between supervision and general contracting is uncontrollable and quantitative. That is, the higher the supervision ability of the government and the public, the greater the punishment, and the greater the optimal probability of the owner's supervision.

When the benefit of the general contractor is maximized, the best probability α'' of the owner's supervision is positively correlated with the penalty multiple n, negatively correlated with the probability ε of the successful supervision of the government and the public, and the probability β of the successful supervision of the owner.

(2) For supervisors and general contractors, the optimal expected return probability of rent-seeking under mixed game is P'. When the probability of rent-seeking is $P > P'$, the general contractor chooses supervision for the safety and quality of the project; when $P = P'$, the owner chooses randomly; when the probability of rent-seeking is $P < P'$, the owner's optimal decision is not supervised.

The optimal probability of rent-seeking between supervisory unit and general contractor P' is positively correlated with owner's supervision cost S and government's supervision success probability ε, negatively correlated with owner's supervision success probability β, penalty multiple n, reward value Z and loss expansion coefficient K.The loss expansion factor K is a quantitative indicator that is independent of the model. By strengthening the supervision ability of the owners, increasing the punishment for irregular behaviors and giving more incentives to the supervision of the government and the public, reducing the supervision cost of the owners can effectively reduce the rent-seeking probability of the supervision unit and the general contractor.

(3) For non-profit organizations such as the government and the public, under the condition of rent-seeking probability P, when the probability of successful supervision by the government, the public and the public is $\varepsilon > \varepsilon'$, the government and the public's income is positive; when $\varepsilon = \varepsilon'$, the government and the public's income is 0; when $\varepsilon < \varepsilon'$, the revenue is negative.

The probability of success of government and public supervision ε', which positively correlated with reward value Z, negatively correlated with supervision cost Y and rent-seeking probability P.When the government and the public get higher profits, the rent-seeking probability of supervision

units and general contractors will be reduced.

6. Conclusion

Taking the construction project and rent-seeking behavior in the whole process of project operation as the research object, established incomplete information game model for various stakeholders, the influencing factors of each behavior are obtained. The conclusions are as follows:

(1) From the perspective of probability of owner's supervision over rent-seeking behavior of general contracting projects, the optimal probability of owner's supervision can be increased by improving the supervision and the owner's ability of non-profit organizations.

(2) By strengthening the supervision ability of the owners, increasing the punishment for irregular behaviors, giving more incentives to the government and public supervision can reduce the rent-seeking probability of the general contractor and the supervising unit; by increasing the incentive value for the government and the public, and reducing the supervision costs of the government and the public, it can effectively improve the supervision ability of the government and the public, thereby effectively avoiding rent-seeking behavior in the project.

Acknowledgements

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