Evolutionary Game Analysis of Engineering Construction Innovation and Local Government Environmental Regulation Strategy

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Abstract. Recent years, with the development of China, an incessant springing up of major engineering projects. Based on the characteristics of the decentralization of local governments in China, whether there are local governments competing to set up major engineering projects at the expense of the environment in order to maintain local economic development. From the perspective of evolutionary game, this paper constructs a game model between engineering construction innovation and local government under the influence of local government's choice of different environmental regulations. Through the dynamic replication equation, the behavior selection path and evolution strategy of local government and engineering construction firms are obtained. The research results show that the strict environmental regulation of local governments and the technological innovation of engineering construction firms can achieve stability at the same time, and the conditions are effective government investment by local governments.

1. Introduction
Since the reform and openness to the outside world, China's economy has entered a stage of rapid development, the central government and local governments have introduced a series of policies to invest a lot of major engineering constructions to satisfy all aspects of people’s demands, such as power station, airport, harbour, highway and so on.

China has been the developing country for many years, in order to pursue economic growth blindly, environmental deterioration, resource depletion, Environmental pollution has become more and more serious problem in last ten years, The pollution of air and water is especially severe, which will do great harm to people’s health. What’s more, a great number of trees have been cut down. The
whole ecological balance of the Earth is being damaged nowadays, so people’s existence is also being threatened. So it becomes more and more important to protect the environment.

Economy development needs urgently new management concepts and technological innovations. Such as the engineering constructions With more efficient, more environmentally friendly. Does China’s local government choose to reduce the environmental standards for major engineering constructions in order to pursue economic growth blindly? These problems gradually entered the topics of scholars.

By combing the research literature of domestic and foreign scholars, it is found that the research on the relationship between engineering construction firm and the environmental pollution of the country is concentrated in the hypothesis of “pollution shelters”. Some scholars believe that engineering construction investment has worsened the environmental quality of the country. Because different engineering constructions have different environmental standards, environmental pollution-intensive engineering construction firms also choose to produce in areas with relatively low environmental standards in order to pursue the lowest cost. In the early stage of economic development, some developing countries introduced preferential policies for engineering construction firms in order to pursue economic growth. They usually chose to lower environmental standards and relax environmental regulations to become a “pollution paradise” in developed countries (Markusen, 1999; List and Co, 2000). On the other hand, the “environmental standard competition” phenomenon will further worsen the environmental quality of the country due to the continuous reduction of environmental standards (Markusen, 1995; Porter, G, 1999). In essence, the related research only analyzes the relationship between engineering construction firms and the country’s environmental pollution, and does not fundamentally solve how to guide engineering construction firms to reduce pollution through technological innovation. Therefore, at present, such issues should be changed from “whether engineering construction produce pollution to the country” to “how local governments guide engineering construction firms to innovate and develop to reduce pollution”. Based on the evolutionary game theory, this paper constructs the evolutionary game model between engineering construction firms and local governments under the influence of different environmental regulations. The dynamic replication equation is used to analyze the evolution of behavior strategies of local governments and engineering construction firms, with a view to promoting localities.

2. the evolution of the game model analysis

2.1. Construction of evolutionary game model

Evolutionary game theory is an iterative game of internal organs in a special group of a certain scale, starting from the conditions of bounded rationality. When the rationality of the players is relatively low or involves collective decision-making, the learning and dynamic adjustment process of the players can be simulated by adopting the “replication dynamic mechanism”. In the whole process of dynamic adjustment, multiple equilibrium will occur. As for which one to choose, the equilibrium depends on the initial conditions of the whole evolution process and the choice of evolution paths. According to the basic principle of evolutionary game, this paper establishes an asymmetric evolutionary game model with engineering construction firms and local governments with bounded rationality as the game, and analyzes the replication dynamics and evolutionary stability strategies of both sides by constructing the replication dynamic equation. According to these, the respective
evolution trajectories and the optimal stability strategy conditions are obtained. The assumptions in the text are as follows:

Hypothesis 1: Assume that there are only two players, namely engineering construction firm and the local government. There are two strategies for engineering construction firm innovation and no innovation, and there are two strategies for local government execution environmental regulation and no implementation. For engineering construction firm, \{innovation; no innovation\} is a combination of two strategies. For local governments, \{execution; no implementation\} environmental regulation are two strategic options.

Hypothesis 2: Under the condition that other factors are not considered, the system composed of the engineering construction firm and the local government is a complete system, and both have limited rationality and learning ability within the system.

Hypothesis 3: Assume that the innovative behavior of engineering construction firm can improve local environmental benefits, and technological innovation is an innovation in reducing pollution emissions. And the innovative behavior can make the engineering construction pollution discharge meet the standard when the government chooses environmental regulation, and for the non-innovative engineering construction pollution discharge is not up to standard.

Hypothesis 4: In terms of game strategy parameter setting, assuming that the engineering construction firm choose technological innovation, it will pay a technical innovation cost \((c)\), at the same time, the government will subsidize engineering construction innovation \((\alpha)\). If engineering construction firm do not carry out technological innovation, it will not be able to obtain subsidies from local governments. Assume that when the engineering construction firm chooses not to innovate, the income is \(P\), and after the green technology innovation, the income is \(P + \Delta P\), \((\Delta P > 0)\). When the local government implements strict environmental regulations, the penalty for the super-successful behavior caused by the non-technical innovation of engineering construction firm is \(\beta\). For local governments, when local governments choose to implement environmental regulation strategies, they need to pay a regulatory cost assumption of \(\gamma\). At the same time, due to the implementation of environmental regulations will bring a green environmental benefits to the local area assumption \(\delta\); If the local government chooses not to implement environmental regulations, there is no need to pay regulatory costs or green environmental benefits. In the asymmetric repeated game, the payment matrix of the stage game is shown in Table 1.

**Table 1** Payment matrix of stage game between engineering construction firm and local government

| Engineering Construction Firm | Local Government       |
|-------------------------------|------------------------|
|                               | Implement | No Implement |
| Innovate                      | \(P + \Delta P + \alpha - C\) | \(P + \Delta P - C\) |
|                               | \(\delta - \gamma - \alpha\) | \(\delta\) |
| No Innovation                 | \(P - \beta\)          | \(P\) |
|                               | \(\beta - \gamma\)      | 0         |
2.2. Dynamic replication equations and stable evolution strategies

The probability of making engineering construction firm innovate is \( x = x(t) \), and the ratio of choosing not to innovate is \((1 - x)\); The probability of choosing to implement environmental regulations in local governments is \( y = y(t) \), and the ratio of choosing not to enforce environmental regulations is \((1 - y)\). The process of simulating the game using the replication dynamic equation is as follows.

The expected benefits of engineering construction firm choosing to innovate are:
\[
U_I = y(P + \Delta P + \alpha - C) + (1 - y)(P + \Delta P - C)
\]

The expected benefits of engineering construction firm choosing not to innovate are:
\[
U_N = y(P - \beta) + (1 - y)P
\]

The average expected return of engineering construction firm is:
\[
\bar{U}_F = xU_I + (1 - x)U_N
\]

The dynamic equation for the replication of innovative strategies chosen by engineering construction firm is:
\[
\frac{dx}{dt} = x(U_I - \bar{U}_F) = x(1 - x)(U_I - U_N)
\]

Bringing \( U_I \) and \( U_N \) into the above equation gives:
\[
F(x) = \frac{dx}{dt} = x(1 - x)[(\alpha + \beta)y + \Delta P - C]
\]

The expected benefits of local government choosing to implement environmental regulations are:
\[
U_Z = x(\delta - \alpha - \gamma) + (1 - x)\delta
\]

The expected benefits of local government choosing not to enforce environmental regulations are:
\[
U_B = x(\beta - \gamma)
\]

The average expected return of local governments is:
\[
\bar{U}_L = yU_Z + (1 - y)U_B
\]

Then the local government chooses to replicate the dynamic equation of the environmental regulation strategy as:
\[
\frac{dy}{dt} = y(U_Z - \bar{U}_L) = y(1 - y)(U_Z - U_B)
\]

Bringing \( U_B \) and \( U_Z \) into the above equation gives:
\[
F(y) = \frac{dy}{dt} = y(1 - y)[\delta - (\alpha + \beta)x]
\]

We first analyze the replication dynamic equations of engineering construction firm choosing technological innovation. Let \( F(x) = 0 \), the stable state of the engineering construction firm can be
obtained, and the stable values are $x_1 = 0, x_2 = 1$. In the formula, $(\alpha + \beta) y + \Delta P - C = 0$ and $y_d = (C - \Delta P)/(\alpha + \beta)$ is obtained.

Analysis of the replication dynamic equations of local government choosing environmental regulations. Let $F(y) = 0$, we can get the stable state of the local government, that is, $y_1 = 0, y_2 = 1$. In the formula, $\delta - (\alpha + \beta)x = 0$, and $x_d = \delta/(\alpha + \beta)$ is obtained. Therefore, there are five partial equilibrium points between the engineering construction firm innovation and the local government environmental regulation strategy: (0,0), (0,1), (1,0), (1,1), (x,y). $x_d = \delta/(\alpha + \beta)$, $y_d = (C - \Delta P)/(\alpha + \beta)$. According to the method proposed by the first-order derivation of the above equations $F(x)$ and $F(y)$ is performed, and the equilibrium point is substituted into the equation. Among the above five equilibrium points, O(0,0) and B(1,1) are the stability points of the evolution strategy. The corresponding strategy combination is (not innovative, not executed); (innovation, execution) two strategies. Figure 1 depicts the phase diagram of the evolutionary game between the engineering construction firm and the local government.

![Figure 1: Phase diagram of the evolutionary game between the engineering construction firm and the local government](image_url)

Among them, the Poly line ADC is the critical line where the evolution strategy converges to different states. When the initial value falls to the right of the critical line, the evolution will eventually converge to B(1,1), which is the (innovation, execution) strategy. When the initial value falls to the left of the critical line, the evolution will eventually converge to the O(0,0) or (no innovation, no execution) strategy.
3. Analysis of the influencing factors of evolutionary stability strategy

In the process of evolutionary game, the choice of engineering construction firm innovation and government regulation is related to the initial state, that is, it is related to the choice of engineering constructions and the choice probability of local government environmental regulation. We can judge the final evolutionary stability strategy point of the game by analyzing the relative position of the saddle point D(x, y). When the initial position falls into the ADCO region, the stable point of the evolutionary game converges to the O point (0,0), that is, the strategy point is selected (not innovative, unregulated), and finally this point will cause both sides of the game to fall into the "prisoner's dilemma." When the initial position falls into the ABCD area, the stable point of the evolutionary game converges to point B (1, 1), that is, the (innovation, regulation) strategy is selected, which causes both sides of the game to move toward the "Pareto optimal" direction. Therefore, we can see that there are two situations in the final execution strategy of the game. One is that the engineering construction firm chooses not to innovate, and the local government chooses to be unregulated, and the two sides fall into the "prisoner's dilemma"; in another case, the engineering construction firm chooses innovation. At the same time, local government chooses to implement environmental regulations, and both parties move toward "Pareto optimality". The choice of the two paths depends on the area where the initial value falls, and then the size of the area to be converted to analyze the path selection problem. The phase map is divided into two regions by the saddle point, namely $S_{ADCO}$ and $S_{ABCD}$. Compare the size of the two to analyze the evolution path. When $S_{ADCO} > S_{ABCD}$, the strategy will eventually evolve to (no innovation, no regulation); When $S_{ABCD} > S_{ADCO}$, the evolutionary stability point will eventually converge to (innovation, regulation); When $S_{ABCD} = S_{ADCO}$, the evolution path will not be judged. Through the phase diagram, we can express the area of the regional ADCO as: $S_{ADCO} = \frac{(x_d + y_d)}{2}$ There are six factors that affect the size, and they are monotonous in size. The specific impact is shown in the following table 2:

It can be seen from Table 2 that when the local government choose environmental regulation, the greater the subsidy for innovative engineering construction firm, the greater the punishment for non-innovative enterprises, the greater the green environmental benefits brought to the social environment, and the evolutionary strategy converges to The greater the probability of (innovation, regulation); When the engineering construction firm choose to innovate, the lower the cost, the greater the probability that the evolutionary strategy will converge to (innovation, regulation).
Table 2: Impact of parameter changes on the evolution of the engineering construction firm and the evolution of the local government environmental regulations

| Parameter change | Saddle point change | Phase area change and evolution direction |
|------------------|---------------------|------------------------------------------|
| $\delta$ ↓      | $x_d$ ↓             | $S_{ABCD}$ ↑, (Innovation, regulation)   |
| $C$ ↓           | $y_d$ ↓             | $S_{ABCD}$ ↑, (Innovation, regulation)   |
| $\Delta P$ ↑    | $y_d$ ↓             | $S_{ABCD}$ ↑, (Innovation, regulation)   |
| $\alpha$ ↑      | $x_d$ ↓, $y_d$ ↓    | $S_{ABCD}$ ↑, (Innovation, regulation)   |
| $\beta$ ↑       | $x_d$ ↓, $y_d$ ↓    | $S_{ABCD}$ ↑, (Innovation, regulation)   |

4. Conclusions and policy recommendations

Based on the bounded rationality of both sides of the game, this paper analyzes the evolutionary strategy choice between the engineering construction firm innovation and local government environmental regulation from the perspective of evolutionary game. The research results show that in the process of the engineering construction firm innovation and local government environmental regulation strategy evolution. The evolutionary set of the two will eventually tend to (innovation, regulation); (not innovative, unregulated). The choice of the two strategies depends on the location of the initial value. When local government implement environmental regulations, it increase subsidies to innovative engineering construction firm to reduce the cost of innovation. At the same time, increase the penalties for non-innovative engineering construction firm, which will converge the evolutionary game. (Innovation, regulation) to achieve "Pareto optimal." The effectiveness of pollution control depends not only on the intensity of government regulation, but also on the choice of government and corporate behavior strategies. Under the environmental regulation, the innovative production costs invested by the engineering construction firm and local governments' incentives for innovation form effective incentives. Based on the research conclusions, the following policy recommendations are given:

The government should increase subsidies for innovative engineering construction firm. For the tangible hand of the government, the engineering construction firm can be encouraged to innovate by increasing investment. According to the different situations of different regional and different industries, the new environmental regulation policies can be used to adjust the intensity of science and technology investment in a targeted manner. Cost-benefits will guide the engineering construction firm to increase technological innovation under the premise of stricter environmental regulations. For example, wind power generation is more environmentally friendly than thermal power generation

4.1 Diversified use of environmental regulation policy tools

When the government chooses an environmental strategy, it should not implement a single policy, and implementing multiple policy implementations is more conducive to achieving a "win-win situation." Attention should be paid to the diversified use of environmental regulation policy tools and the effectiveness of environmental policies through a variety of mechanisms. Traditional mandatory
environmental regulation policy objectives are costly to achieve, and market-based policy instruments such as pollution licensing systems enable the engineering construction firm to achieve emissions targets at the lowest cost. In addition to the implementation of mandatory means and economic means, the government can also mobilize the initiative and consciousness of the engineering construction firm to participate in environmental governance, and encourage the engineering construction firm to implement strict environmental standards on a voluntary basis.

4.2 Improve the performance evaluation system

Reform and improve the performance appraisal system for local governments. Incorporate regional environmental quality, environmental protection performance and other indicators into the performance evaluation system of local governments, and refine these environmental indicators to make them more operable.

References
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