Game behavior among multi stakeholders in the process of haze control*

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Abstract. The contradiction between economic development and pollution control is becoming increasingly prominent, which is a huge problem that China's economic development transformation must face and solve at this stage. Among them, the governance of haze is the crux because of its great impact on health. The game behavior of haze governance involves many subjects. After considering the specific situation of the game in reality, this paper constructs a mixed strategy model of multi stakeholders, including the central government, local government, enterprises and the public. In addition to the direct participation of local governments and enterprises in the game, the central government and the public indirectly participate in the final game results through supervision and public opinion. Based on the analysis of the game results, in order to better control the haze and achieve green development, enterprises should strengthen environmental self-discipline, local government and central government should cooperate effectively, and the public should actively participate in it to form a strong influence of public opinion.

1. Research Background
With the rapid development of economy, environmental problems have become increasingly prominent, and haze has gradually become the focus of attention, causing great inconvenience and threat to people's lives. According to statistics, in 2013, nearly 30 regions in China were shrouded in haze. In the following years, the state issued a lot of haze control policies, aiming to create a comfortable environment with a clear sky for everyone. The governance of haze is not a matter of one person and some institutions, involving multiple stakeholders, including the government, enterprises and individuals. Only by correctly handling the relationship between the various stakeholders, can haze governance really play a maximum effect.

2. Literature Review
Relevant literature shows that after the comprehensive outbreak of haze in 2013, the government actively formulated and implemented haze governance policies, and relevant scholars immediately launched research work on haze governance. Since 2014, the research on the game of haze governance has come into everyone's vision, mainly including four directions: the game between government and enterprises, the game between central government and local government, the game between local governments and the game between enterprises and the public.

Chu ZP et al. constructed a non-cooperative evolutionary game model including the central government, local government and pollution enterprises, and believed that the central government
should make efforts in strengthening the centralized environmental management, establishing local emission reduction compensation mechanism, improving the environmental tax collection standard and guiding public supervision[1]. Bai LY, Fang H and Yin L all put forward the game between the central government and the local government on haze governance. The central government is the initiator and promoter of haze governance, while the local government is the real executor of regional haze governance. Therefore, there will be a game between the two because they pursue the maximization of their respective interests[2-3]. Pan F et al. and Zhou et al. and Zhao XF et al. all put forward the game between local governments. They think that because the functions of local governments are decentralized and intersected, "each management section", the horizontal communication network is blocked, and the system design is unreasonable, the effect of haze governance is very little, so the key of haze governance is the cooperation between local governments to carry out cross regional collaborative governance[4-6]. Sun L and Sun SR studied the cross regional air pollution control in Beijing, Tianjin and Hebei by constructing the characteristic function of cross regional cooperative pollution control and the participation function of fuzzy cooperative game, and found that the formulation of the coordination mechanism of economic benefits of joint pollution control can effectively stimulate the participants and promote the effective implementation of cross regional joint pollution control[7]. Ma X and Zhang GX constructed an asymmetric evolutionary game model of collaborative governance of haze in Beijing, Tianjin and Hebei from the perspective of ecological compensation and ecological claims, and found that reasonable standards of ecological compensation are essential for energy conservation and emission reduction of enterprises[8]. Wang HM et al. established the evolutionary game model between the central and local governments, local governments and enterprises, and constructed the best regulation strategies of both sides from the two dimensions of the best regulation effect and regulation intensity. The research found that the central and local governments should respectively play a role in the allocation of special funds for governance and the collection of appropriate environmental taxes[9]. Du JG et al. and Shi SJ, Wang XP and Chang JW et al. proposed that the public, as the biggest victim of haze, should be added to the game model. Through the cooperation entrustment between the public and the government, the two mechanisms jointly supervise and restrict enterprises, and ultimately achieve win-win results[10-12]. To sum up, at present, scholars' research on the game of haze governance is limited to individual stakeholders, and lack of overall consideration and control of multi stakeholders. In this paper, the central government, local governments, enterprises and the public are included in a game model, which comprehensively considers the rights and interests of multiple stakeholders, and then gives a more effective haze control plan.

3. Model Building

After considering the specific situation of the game in reality, this paper constructs a mixed strategy model of multi stakeholders, including the central government, local governments, enterprises and the public, as shown in Figure 1 below. In addition to the direct participation of local governments and enterprises in the game, the central government and the public have an impact on the final result of the game through indirect means such as supervision and public opinion.
3.1 Model Assumptions

a. Assuming that the central government, local government, enterprises and the public are rational people, they will make the most favorable decisions after weighing their own costs and benefits;

b. Assuming that enterprises and local governments as the main players in the game are static games with incomplete information;

c. Local governments should accept the supervision of the central government while supervising enterprises. The central government will give some punishment if its supervision is not effective; the public will prefer environmental protection enterprises when making purchase decisions, so as to improve the competitiveness and social status of environmental protection enterprises, while for the enterprises with serious pollution, they will be excluded from the selection range by the public, thus affecting the future development of these enterprises; the effective treatment of local pollution will improve the local government's role in the public. The status of the mind helps to build a good social image;

d. Due to the externality of the environment, environmental pollution will lead to the decline of the overall welfare of the society, which should be borne by the local government.

3.2 Relevant Parameters

A: Cost of corporate pollution control
B: Income of corporate pollution control
C: Supervision cost of local government
D: Degree of social status decline caused by corporate pollution control
E: Degree of social image of local government will be improved if there is no pollution
F: Fine of local government for corporate pollution control
G: Degree of social welfare decline caused by corporate pollution
H: Local pollution Leading to fines imposed by the central government on local governments

Assuming that: \( B - D - F < A < B - D \) and \( F > C \)

As the biggest victim of haze weather, the public, through the supervision of enterprises and local governments, joins in the process of haze treatment. If enterprises ignore pollution treatment, the public will form a prejudice against the enterprise, which will reduce its social status, that is, parameter D. At the same time, if the local pollution treatment is in order, it will naturally improve the status of the government in the public mind and establish a good social shape. The important role of the central government cannot be ignored. When there is pollution in the local area and there is no governance action, the local government should be punished to achieve the purpose of strengthening the local
government's supervision and effectiveness, that is, parameter H. Adding these three parameters to the game model makes the model more complete and more practical.

3.3 Game Model Establishment
After the above analysis, the mixed strategy model of multi stakeholders is established as follows:

| Direct Stakeholders | Enterprises |
|---------------------|-------------|
| Governance          | Non-governance |
| Local governments   | (E − C, −A)  | (−C + F − G − H, B − D − F) |
| Non- supervision    | (E, −A)      | (−G − H, B − D) |

Table 1. Mixed strategy game of multi stakeholders

Note: In this game, local governments and enterprises make decisions as direct participants, and the central government and the public as indirect participants participate in decision-making by influencing local governments and enterprises.

4. Model analysis
For the above game model, there are four strategies:

**Strategy One**: When the local government and enterprises choose to (unsupervised, governance), the local government will win a good social image because of the corporate governance environment; the enterprise will pay for the pollution governance costs, and the enterprise, as a rational person, will choose not governance to realize its own interests after perceiving the unsupervised behavior of the local government Maximization.

**Strategy Two**: At this time, both parties choose (no supervision, no governance). For enterprises, although the social status will decline due to no governance of pollution, the cost of governance will be eliminated and the benefits will eventually increase. However, local governments will be punished by the central government for this kind of inaction, and they will also be responsible for the decline of social welfare. At this time, local governments are rational, in order to pursue the maximization of self-interest, we will adjust the corresponding strategies and choose supervision.

**Strategy Three**: At this time, both parties choose (supervision, non-governance). Due to the pollution of enterprises, the local government still has to pay for the decline of social welfare, pay the fine imposed by the central government, and pay a certain cost of supervision, but it will get a large fine for enterprises, which is a wise move of the local government. For enterprises, non-governance not only reduces the social status, but also to bear a large amount of fine, pollution control is its inevitable choice.

**Strategy Four**: At this time, both parties choose (supervision, governance). Because of the high consciousness of enterprises in pollution control, local governments will gradually relax the supervision of enterprises in order to save the cost of supervision.

According to the above analysis, there will be no pure strategy Nash equilibrium, but mixed strategy Nash equilibrium.

4.1 Expected Return of Mixed Strategy
Suppose the probability of local government supervision is $P_1$, the expected revenue is $U_1$, the probability of enterprise pollution control is $P_2$, and the expected revenue is $U_2$. According to the above game model, the expected revenue of local government is expressed as follows:

$$U_1 = P_1 \cdot P_2 \cdot (E - C) + P_1 \cdot (1 - P_2) \cdot (-C + F - G - H) + (1 - P_1) \cdot P_2 \cdot E + (1 - P_1) \cdot (1 - P_2) \cdot (-G - H) \quad (1)$$

Derivation from the above formula, let $\frac{\partial U_1}{\partial P_1} = 0$, can get $P_2 = \frac{F - C}{F}$, that is the condition of maximizing the income of local government.
Similarly, the expected return of an enterprise is expressed as:
\[ U_2 = P_A^* (1 - P_A^*) (B - D - F) + (1 - P_A^*) (1 - P_B^*) (B - D) \]
(2)

Derivation from the above formula, let \( \frac{\partial U_2}{\partial P_2} = 0 \), can get \( P_1 = \frac{A + B - D}{F} \). That is to say, if an enterprise wants to maximize its revenue, it needs to meet this condition.

The equilibrium result of the game model is that both local government and enterprises realize the maximization of revenue. According to the above results, when the probability of local government supervision is \( \frac{A + B - D}{F} \), the revenue is the maximum. And when the probability of corporate pollution control is \( \frac{F - C}{F} \), the revenue is also the biggest one. When \( P_1 > \frac{A + B - D}{F} \), local government will choose supervision; When \( P_1 < \frac{A + B - D}{F} \), local governments will choose not; And when \( P_1 = \frac{A + B - D}{F} \), local governments choose mixed strategies; When \( P_2 > \frac{F - C}{F} \), enterprises will choose not to control pollution; When \( P_2 < \frac{F - C}{F} \), enterprises will choose to control pollution; And when \( P_2 = \frac{F - C}{F} \), enterprises choose mixed strategy.

According to the probability of equilibrium, the probability of local government's supervision is positively related to the cost of enterprise's pollution control and the income of enterprise's non-pollution control. That is to say, when the cost of enterprise's pollution control is very high or the income of enterprise's non-pollution control is very high, the enterprise will be slack in pollution control. At this time, the government should strengthen supervision to stop this kind of incorrect behavior. The decline of social status caused by the non-governance of industrial pollution is negatively related to the fine that the local government has detected that the non-governance of enterprise pollution. That is to say, when the enterprise ignores environmental governance, it will lead to a serious decline of its social status, and pay a large amount of fine. At this time, the consciousness of enterprise pollution control will be improved, and the supervision of the government can be relaxed. Based on this, it can be seen that the public, as an interest subject, has influenced the result of the game through its influence on the social status of the enterprise. The stronger the public's awareness of environmental protection, the greater the impact on the game. When the social status of the enterprise declines more than the cost of governance and the income of non-governance due to pollution, the enterprise will consciously choose to govern the pollution and no longer need the supervision of the government.

The probability of corporate pollution control is related to the supervision cost of the local government and the fines for the non-governance of the enterprise. When the supervision cost of the government is high, the government will relax the supervision, and the enterprise will take advantage of this opportunity not to control the pollution. When the fines for the non-governance of the enterprise are high, in order to avoid being punished, the enterprise will consciously choose to control the pollution. The reason why the central government has no influence on the result of the game is that in order to study the simple hypothesis, no matter whether the local government supervises or not. As long as there is pollution by enterprises in this place without treatment, the central government will impose the same fine on the local government. Obviously, this is inconsistent with the reality. The central government will impose different levels of fines according to the efforts of the local government to monitor the pollution by enterprises, which will influence the outcome of the game.

4.2 Response Function of Mixed Strategy
The response function of the game is a function of the best response decision of either enterprise or local government to each possible probability distribution of the other. Suppose that the revenue of local government's non-supervision is \( R_1 \), and the revenue of enterprise's non-pollution control is \( R_2 \).
According to the game model, when the local government does not supervise, the revenue is \( R_1 = P_2^*E + (1 - P_2^*)(-G - H) \),  where  \( P_2^* \) is the probability of the enterprise to control the pollution, which is between 0 and 1. When the enterprise does not control the pollution,  \( P_2 = 0 \), the revenue of the local government does not supervise, \( R_1 = -G - H \), that is, to bear the loss of social welfare and the punishment of the central government. When the enterprise manages the pollution, \( P_2 = 1 \), the revenue of the local government is \( R_1 = E \)  That is to say, it has established a good social image due to the effective treatment of pollution. Take  \( P_2 \) as the horizontal axis and  \( R_1 \) as the vertical axis, and make the figure2.

Connect two points \((0, -G - H)\) and \((1, E)\), and it intersects the horizontal axis at \((P_2^*, 0)\), so  \( P_2^* \) is the best choice for enterprises to choose pollution control; assuming that the central government will increase its punishment due to the local government's non-supervision, from \( H \) to \( H' \), at this time, if the probability of enterprises' pollution control is still  \( P_2^* \) and the income of local government's non-supervision becomes negative, the government will choose to increase supervision, and the probability of enterprises' pollution control will rise from \( P_2^* \) to \( P_2^*\prime \), a new equilibrium is formed, that is \((P_2^*\prime, 0)\). According to the above analysis, we can recognize the role of the central government in the game. The central government increases the punishment for the local government's inaction or low effectiveness, which can improve the local government's enthusiasm for action, make it more conscientious, and then increase the probability of corporate pollution control, and provide a more comfortable and clean living environment for everyone.
is between 0 and 1. When the local government chooses not to supervise, that is $P_1 = 0$, the income of the enterprise not to control pollution $R_2 = B - D$, although it wins the short-term income, it leads to the decline of social status, but the enterprise not to control pollution is still profitable; when the local government supervises, that is $P_1 = 1$, the income of the enterprise not to control pollution $R_1 = B - D - F$, at this time, it also bears the large amount of fines from the local government. Take $P_1$ as the horizontal axis and $R_2$ as the vertical axis, and make the figure 3.

Connecting $(0, B - D)$ and $(1, B - D - F)$ intersects the horizontal axis at $(P_1^*, 0)$, that is to say, the optimal supervision probability of local government is $P_1^*$, in order to better control pollution, it will increase the punishment to the enterprises that do not control pollution, from $F$ to $F'$, at this time, if the local government still maintains the previous supervision probability $P_1^*$, the income of enterprises that do not control pollution will become negative value, and the enterprises will increase the treatment of pollution to achieve the desired effect. However, according to the figure above, in the long run, due to the improvement of enterprises' enthusiasm for pollution control, the probability of local government supervision will continue to decrease until a new equilibrium $(P_1^*, 0)$, is reached again. Therefore, to increase the punishment of enterprises that do not control pollution can only have a temporary effect, not a long-term solution.

5. Suggestions and Countermeasures for Haze Control

Through the analysis of the mixed strategy model of multi stakeholders, including the central government, local government, enterprises and the public, the future interest groups can make efforts in the following three aspects.

a. Enterprises: Strengthen social responsibility consciousness and environmental self-discipline

As the main source of pollution, enterprises should have a higher awareness of environmental protection and self-discipline, consciously reduce the production of high pollution and high emission products, strengthen independent innovation, and transform into energy-saving and emission reduction enterprises. For some inevitable production pollutants, they should be cleaned and discharged after reaching the standard, instead of being arbitrarily discharged into the air. These enterprises also should establish a good public image, strengthen self-discipline, deeply understand the importance of environmental protection, take environmental pollution as an enterprise image input, record it in the production cost, comprehensively consider the income and the cost of environmental pollution, and make the best choice.

b. The central and local governments: Closely cooperate with each other in implementing policies, and build a long-term supervision mechanism of the central government to the local government and the local government to the enterprises

As the whole of haze control, the central government should make an overall plan for the controller and the policy maker of haze control, take into account the development of each region, formulate a reasonable ecological compensation and claim mechanism, and make the most appropriate strategic arrangements. Local governments should actively respond to the measures of the central government and work steadily and effectively on the front line of haze control. The central government should test and supervise the local government's governance effect, and give appropriate rewards and punishments. It is not allowed to indulge the local government's free supervision, let alone to ignore the environmental damage in the pursuit of economic development, which creates certain pressure on the local government. Here, it should be emphasized that the central government's supervision and punishment of the local government will lead to Haze control has more ideal results, which can not only improve the supervision of local governments, but also improve the probability of corporate pollution control in the long run. For local governments, we should constantly reduce the cost of supervision, and include the results of environmental governance into the performance appraisal, which will play an incentive role in the effective supervision of local governments. However, the local government's increasing punishment on the polluting enterprises is not an effective way to control the haze. In the short term, the probability of the enterprises to control the pollution will increase, but in the long term, it will encourage the laziness of the local enterprises, reduce the supervision, and be harmful to the long-term governance mechanism
of the haze.

c. The public: Actively participate in haze control

As the direct victims of haze, the public should actively participate in the haze governance process, be good at using social media public opinion to supervise the behavior of enterprises, form a positive social atmosphere, and then gather into a strong social influence. Through the identification of polluting enterprises, we boycott those enterprises that neglect environmental protection and arbitrarily discharge pollutants, so that they can pay for environmental pollution. When the public's influence is large enough, the government's supervision is no longer needed, and enterprises will consciously put environmental protection in the first place. Of course, for the local government that actively supervises the corporate governance, the public should give it some affirmation, so that it can establish a better social image, which is also an incentive for the local governance to actively act.

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