Analysis of the regulatory game of government environmental protection departments on corporate pollution control

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Abstract. In recent years, China's rapid economic growth at the same time, promote the construction of ecological civilization, and constantly improve the enterprise pollution control policy, optimize the environmental protection department on the supervision of corporate sewage behavior, and promote the transformation of the country's ecological civilization and a strong country. However, there are still many enterprises still lack of environmental awareness, in order to maintain their own interests, constantly "drilling" system "loopholes", do not take the initiative to invest in pollution control, choose to indulge in the problem of sewage disposal, falsification of enterprise data, so as to obtain improper excess earnings, resulting in a serious negative externality. Serious negative externalities. In this regard, this paper will use the game model to analyze the government's environmental protection department to govern the degree of strictness, improve the enterprise pollution violation emission punishment mechanism, etc., the impact of the change of these parameters will make the enterprise pollution control behavior to improve. The results of the study show that increasing the management system of environmental protection department personnel and enhancing the punishment for corporate pollution violation discharge behavior can effectively reduce the emergence of corporate pollution violation behavior.

1 Introduction

China in recent years, the economy has gained high speed development, but many enterprises pollution emission there is a big problem, on China's ecological environment and the health of the residents to produce serious harm, the country has more rough, high energy consumption enterprises, the country in recent years, pay more attention to the environment and the economic development of the coordination of the problem, the government environmental protection departments of the enterprise governance and not perfect, the cost of pollution is far less than the pollution benefit, the enterprise for the pursuit of excess profits, choose to Violation of emissions, resulting in serious air pollution and water pollution problems. According to China's Ministry of Ecology and Environment in 2023 issued by China's 209 key lakes (reservoirs) monitoring data show that the main cause of water pollution is industrial pollution, industrial pollution process, a large amount of industrial wastewater is discharged into the river and into the urban groundwater, not only caused

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serious ecological damage, but also pollute the residents of the daily drinking water resources. China's air pollution control has improved in recent years, but in recent years, patients with respiratory diseases have increased significantly, urban haze appears from time to time, so the corporate sewage management is imperative [1].

In order to better manage the problem of corporate sewage violations, government regulators to regulate corporate sewage, for the establishment of corporate sewage licensing rights, with sewage licensing rights of enterprises, the need for self-testing, take the initiative to assume responsibility for the control of sewage and the need for timely reporting to the environmental protection department of the pollution data. In order to strengthen corporate pollution control, the state also implemented the 'fee to tax', the implementation of environmental protection tax, environmental protection supervision and pollution tax separate. However, the implementation of the tax system, so that the environmental protection department's penalties are limited, and the tax department can not directly access the enterprise's pollution emissions data, many enterprises, the cost of pollution emissions is less than the unreasonable emissions to obtain the benefits, and thus the pursuit of private interests, and the environment has caused serious negative externalities, seriously harming the atmosphere, water resources, such as the 'public interest The 'public interest' of the atmosphere and water resources has been seriously harmed. Small and medium-sized enterprises lack of environmental expertise and pollution control equipment can only rely on pollution detection agencies to regulate corporate pollution, and third-party agencies conspire and collusion, maliciously tampering and misrepresentation of false corporate data, falsified test results, resulting in environmental protection departments of the pollution control difficulties, making the problem of corporate sewage cannot be effectively managed. This status quo, this paper through the government environmental protection departments and sewage enterprises as the main game to build a bilateral game model, analyse the two-face different policy background and punishment of decision-making behaviour, and according to the results of the analysis of China's environmental protection departments on the governance of corporate sewage management and the improvement of the mechanism, to put forward a reasonable policy recommendation [2].

2 Literature review

In the analysis of the game behavior between government environmental protection departments and sewage enterprises, the government environmental protection departments were the regulatory subject, and sewage enterprises were the regulatory object. The government environmental protection departments restricted and regulated the sewage discharge behavior of enterprises by charging fines, setting discharge rights, and formulating sewage regulations [3]. The primary purpose of the enterprises was to pursue their own maximum interests within the law, with little consideration for their impact on the public interest and the negative externalities caused by sewage problems [4]. After weighing the high and low interests, enterprises tended to choose high-yield behaviors over compliant ones. This study sorted out the regulatory instruments implemented by the government environmental protection departments and the responses of enterprises to these instruments in order to pave the way for constructing model parameters.

2.1 Regulatory approach to business discharges

The regulation of enterprise emissions was primarily carried out through mandatory supervision by environmental protection departments and self-supervision by enterprises. Environmental protection departments limited enterprise discharges mainly through administrative punitive measures, economic regulation, and defining the right to discharge.

Li believed that the government's administrative approach involved developing environmental policy-related regulations for sewage enterprises, conducting inspections, and imposing penalties [1]. The government also established a sewage rights trading mechanism, which privatized the external environment of enterprises, converting the external impact of sewage enterprises on environmental resources into internal concerns, as a way to address market failure caused by externalities. Enterprises obtained government-issued emissions licenses and controlled pollution emissions through self-monitoring. Huang argued that, at the time, the overall quality of enterprise self-monitoring was low, with loopholes in monitoring methods, falsified data, and incomplete and delayed public disclosure of enterprise data [2, 3]. Zhang pointed out that with the implementation of the environmental protection tax, tax departments, rather than environmental protection departments, were responsible for collection, which led environmental protection departments to focus more on detection, while their enforcement was insufficient. This created opportunities for enterprises to engage in rent-seeking behavior to avoid taxes and fees. Zhang suggested that environmental protection policies should increase the cost of compliance for enterprises while reducing excessive government intervention [4-6]. He and Lu emphasized that stability in the personnel of environmental protection departments allowed for richer experience in environmental management and enterprise sewage control methods, making personnel stability an effective solution to enterprise pollution management [7-9]. Wu and Hu et al. believed that increasing environmental taxes could help promote reasonable sewage management by enterprises, and strengthening the government's green transformation policy was seen as the best solution for addressing enterprise pollution in developing countries. Strengthening these policies was considered essential for improving environmental governance in developing countries [10].

2.2 Reasons for non-compliance by enterprises

Non-compliance by enterprises with emission controls was mainly due to unfavorable government regulation and the fact that the enterprises' own pollution costs were smaller than their pollution benefits. Some enterprises, in pursuit of additional profits, only considered private interests and, under the premise of limited penalties from environmental protection departments, chose to pay fines and reduce pollution control efforts in order to obtain more revenue. However, this behavior brought additional revenue in the short term, while in the long term caused serious damage to the surrounding environment, threatened the health of residents, led to more legal disputes, tarnished the reputation of the enterprise, and eventually faced stricter state control, suspension, and rectification. Lu et al. and Liu et al. pointed out that due to the high degree of privacy concerning enterprise pollution data, varying sewage testing programs across enterprises, and differing understandings among sewage supervisors regarding testing methods, loopholes existed in the enterprise’s self-monitoring of sewage emissions, highlighting the need to regulate these methods [6]. Government environmental protection departments interfaced directly with enterprises, and the monitoring data provided by environmental department personnel made it inevitable for corruption to occur [8]. In order to avoid government punishment, Kai Hu and Daqian Shi showed that collusion between officials and enterprises in China's environmental protection efforts existed, and adjusting the internal personnel management system could promote the development of a green economy [11]. Wei et al. also showed that public demand for local environmental protection departments could effectively improve environmental pollution control, but unfavorable government regulation led to protests and resistance from local residents, reducing government credibility and affecting policy implementation [12]. He et al. demonstrated that strong penalties for core enterprises could effectively promote pollution control among small and medium-sized enterprises. Many small and medium-sized

enterprises did not have sufficient funds to invest in high-quality environmental testing equipment and professional personnel and required government subsidies or third-party agency testing [2]. However, collusion between third-party agencies and enterprises in falsifying data led to increased costs for government environmental protection departments to monitor and control pollution.

3 Analysis of the game behaviour

3.1 Assumptions of the model

There are two players in the game model: the government environmental protection department and the sewage enterprises. The government environmental protection department is the supervising party, which inspects the enterprise's sewage discharge situation, and fines the enterprise if it is found to be in violation of the sewage discharge conditions; if the enterprise's sewage discharge situation is good, it will subsidise the sewage enterprise's pollution control. Sewage enterprise is the supervised party, sewage enterprise's primary purpose of business is to maximise the pursuit of corporate profits, to obtain excess earnings, in the enterprise sewage violation of the conditions, in the face of the government's supervision of the main measure of sewage treatment costs and treatment of revenue issues, the enterprise can get higher corporate earnings, will not hesitate to choose the violation of the sewage and excess earnings, in the face of the government's supervision of the main measure of sewage treatment costs and treatment of revenue issues, in the face of the government's supervision of the main measure of sewage treatment costs and Governance Benefits

In this game behaviour analysis, the two strategy choices of the government environmental protection department are: strict regulation and no strict regulation, and the strategy choices of the sewage enterprises are: violation of sewage discharge and no violation of sewage discharge.

In this game behaviour, both the government environmental protection department and the discharging enterprises are risk neutral. The government environmental protection department will maximise its own interests under legal conditions, while the sewage enterprise will pursue the maximisation of corporate profits under the risk of loss that it can bear.

The problem of illegal discharges by enterprises will definitely be detected only under the condition of strict supervision by the government, and the illegal discharges by enterprises will be concealed under the condition of non-strict supervision by the environmental protection department. The normal discharge benefit to the discharging firm is zero.

3.2 Parameter settings and descriptions

Where C_0 represents Costs of less stringent regulation by environmental authorities. C_1: Costs of strict regulation by environmental authorities. B_1: The environmental protection department strictly regulates the discharge of pollutants by enterprises, and obtains excellent political results, with reasonable material incentives and job promotions from superiors.B_2:The environmental protection department strictly regulates corporate emissions, improves local environmental conditions, brings benefits to neighbouring residents, and gains reputation and government credibility. C_2: The lack of strict supervision by the environmental protection authorities has resulted in the enterprise's sewage problem being reported by the local population and severely punished by its superiors. B_3: Illegal proceeds obtained through corruption and collusion with enterprises in the absence of strict supervision

by the environmental protection authorities. B_4: Environmental authorities are not strictly regulated, personnel management requires less time-consuming work, and environmental authority employees receive more leisure costs. S_0: The cost to the enterprise of not discharging in violation of the law. S_1: Costs of non-compliance by enterprises. K: Direct financial penalties and production limitations imposed on enterprises that are found to be in violation of environmental regulations. L: Costs of legal defence and reputational damage suffered by local populations affected by the health and environmental damage caused by the illegal discharge of pollutants by enterprises. N: Excess gains from enterprises whose emissions violations are not detected by the environmental authorities. M: Enterprises with good management of pollution emissions are subsidised by the environmental authorities for investment in environmental management equipment. The game model is built based on the above assumptions and parameter settings displayed in Table 1.

Table 1. The game model

	Corporate sewage violations	Enterprises do not violate emissions
Strict regulation by the environmental protection department	$(B_1 + B_2 + K - C_1, -S_1 - K - L)$	$(-C_1 + B_2 - M, -S_0 + M)$
Lack of strict regulation by the environmental protection department	$(-C_0 - C_2 + B_3 + B_4, -S_1 + N - B_3)$	$(-C_0 + B_4 - M, -S_0 + M)$

4 Analysis of Nash equilibrium results

4.1 Mixed-strategy optimal choices for discharging firms

Assuming that the environmental protection department strictly regulates with probability a, the probability of not strictly regulating is (1-a); and the firm violates emissions with probability b, the probability of not violating emissions is (1-b). So the mixed strategy of the environmental protection department is (a,1-a), and that of the sewage firm is (b,1-b). Based on the game matrix and the above assumptions the expected utility function of the environmental sector is derived as $V_1 = a\big(b(B_1 + B_2 + K - C_1) + (1-b)(-C_1 + B_2 - M)\big) + (1-a)\big(b(-C_0 - C_2 + B_3 + B_4) + (1-b)(-C_0 + B_4 - M)\big) = ab(B_1 + K + C_2 - B_3) + a(-C_1 + B_2 + C_0 - B_4 + b(-C_2 + B_3 + M) + (-C_0 + B_4 - M)$. Differentiating the expected utility function for the environmental sector.

$$V_1' = b(B_1 + K + C_2 - B_3) + (-C_1 + B_2 + C_0 - B_4) \quad (1)$$

The optimal solution is obtained as.

$$b^* = (C_1 - C_0 + B_4 - B_2)/(C_2 + B_1 - B_3 + K) \quad (2)$$

The analytical interpretation of the optimal solution b^* is that when the probability of a firm violating emissions is greater than b^*, the environmental protection department should choose to strictly regulate at this time; while when the probability of a firm violating emissions is less than b^*, the environmental protection department will choose not to strictly regulate at this time. The same reasoning leads to the optimal choice of mixed strategy for the environmental sector.

$$a^* = (S_1 + B_3 - N)/(B_3 - K - L - N) \quad (3)$$

The analytical interpretation of the optimal solution a^* is that when the probability of the environmental protection department choosing to strictly regulate is greater than a^*, the discharging enterprise will choose not to discharge in violation of the law; when the

probability of the environmental protection department choosing to strictly regulate is less than a^*, the discharging enterprise will choose to discharge in violation of the law.

According to the definition of Nash equilibrium, each participant's choice is optimal given the other party's mixed strategy, so the only Nash equilibrium of this game matrix is that the enterprise chooses to violate the emission with probability b^*, and the environmental protection department imposes strict regulation on the emission enterprise with probability a^*.

4.2 Analysis of Nash equilibrium results

Based on the above conclusions.

$$b^* = (C_1 - C_0 + B_4 - B_2)/(C_2 + B_1 - B_3 + K) \quad (4)$$

Analyse and explain the optimal choice of a discharging firm to choose to breach the law with probability b^*.The numerator is $(C_1 - C_0 + B_4 - B_2)$, $C_1 - C_0$ refers to the cost of strict regulation of the environmental protection department than the cost of not strict regulation, so there is $(C_1 - C_{0)}$ greater than 0, and $(B_4 - B_2)$ refers to the environmental improvement of the residents of the environmental protection department of the reputation of the affirmation and support of the environmental protection department and the environmental protection department of the difference between the cost of leisure gained by the lax regulation, is usually not the dominant role, so $(C_1 - C_0)$ is greater than $(B_4 - B_2)$, the numerator is greater than 0.

The denominator is $(C_2 + B_1 - B_3 + K)$, which means mainly the difference between the government benefits brought about by the environmental protection department's strict control of the enterprise's sewage discharge and the benefits obtained by the bribed sewage enterprise, and is usually considered to be a value greater than zero. So the combination of analysis 1, when other conditions remain unchanged, the numerator becomes larger, the probability of enterprises choose to violate the sewage increase; denominator becomes larger, the probability of enterprises choose to violate the sewage decrease.

According to the b^*formula, $(C_1 - C_0)$: the difference between the cost of strict and non-strict regulation by the environmental protection department is directly proportional to the probability of enterprises choosing to discharge in violation of the law; when the environmental protection department needs to pay more manpower and material resources for strict regulation, as well as capital investment, the greater the difficulty in the implementation of strict regulation, and the more likely that the enterprises will choose to discharge in violation of the law.

According to the b^* formula, the probability of enterprises choosing to discharge is directly proportional to the leisure time gained by the environmental protection department not strictly regulating and inversely proportional to the reputation and other benefits gained by the environmental protection department strictly regulating, and people always tend to complete the task with greater ease, so the lazy regulation to gain more leisure time makes the more gaps in violation of the sewage enterprises and the government to gain more public support and reputation, making the environmental protection department staff more The government gains more public support and popularity, which makes the staff of the environmental protection department more motivated and makes the supervision of sewage discharge more strict.

According to the b^* formula, the stricter the supervision of the environmental protection department by the higher authorities, the more the environmental protection department will be prompted to monitor and regulate the environmental protection department, the stronger the governance, the less the enterprises will choose to violate the emissions; the more generous the rewards for the environmental protection department's excellent performance by the higher authorities, the more efficient the environmental protection department will be

prompted to do its work, and the lower the probability of the enterprises to violate the emissions; the greater the amount of fines imposed on the enterprises by the government, the more the enterprises will be exposed to violation of the risks. The greater the amount of government fines, the greater the risk of non-compliance faced by enterprises, enterprises are more inclined to choose not to violate the sewage; enterprises for the environmental protection department of the greater degree of bribery, environmental protection departments will be more prone to corruption, for the violation of sewage enterprises to a higher degree of tolerance, enterprises will have more opportunities to violate the sewage.Based on the above conclusions.

$$a^* = (S_1 + B_3 - N)/(B_3 - K - L - N) \quad (5)$$

Analyse and explain the optimal mixed-strategy choice of the environmental authority to impose strict regulation with probability a^*: The numerator is $(S_1 + B_3 - N)$, $(S_1 + B_3)$ representing the costs incurred by the enterprise when it violates the sewage regulations, including the cost of the basic inputs for the violation and the cost of the bribery, and N representing the excess benefits obtained by the enterprise from the violation, which is usually considered to be greater than the cost of the violation when the enterprise has a tendency to violate the sewage regulations, so that N>$(S_1 + B_3)$, and the numerator is less than 0.

The denominator is$(B_3 - K - L - N)$. Often, enterprises choose to violate emissions, and the economic cost of bribing environmental protection personnel is lower than the excess benefits they receive from violating emissions, so there is a B_3 less than N and the denominator is less than 0.Readjusting the expression for a^*in the light of analyses 1 and 2= $(N - B_3 - S_1)/(K + L + N - B_3)$

According to the expression a^*, the probability of the environmental protection department to impose strict supervision is inversely proportional to the cost of the enterprise's illegal discharge, the greater the risk of the enterprise's illegal discharge, the more the enterprise will be inclined to choose a reasonable discharge, the environmental protection department to reduce the difficulty of supervision; the enterprise, in order to achieve the purpose of the illegal discharge will not be detected to the government departments for bribery, the greater the amount of bribe, the environmental protection department personnel will be tolerant of the enterprise's violations, the environmental protection department The greater the amount of bribe, the more likely the environmental protection department personnel will tolerate the company's illegal behaviour and the less likely the environmental protection department will impose strict supervision. When the sewage enterprises through the violation of sewage can obtain a large excess revenue, sewage enterprises do not hesitate to choose, this time the environmental protection department often detects the intelligence, but also will certainly increase the supervision of the sewage enterprises.

The probability of the environmental protection department choosing to strictly regulate is positively correlated with the amount of fines imposed on the enterprises for non-compliance and the hidden costs (legal defence costs, loss of reputation, etc.) of causing ecological damage, so that when the additional costs of non-compliance are too large, and the fines to be paid are large, the enterprises will be afraid of the greater risk of non-compliance and the pressure on the continued operation of the enterprise to engage in non-compliance, and will not dare to carry out non-compliant behaviour. The environmental protection department does not need too much supervision, the enterprise will consciously comply with the rules and regulations of the government.

Improving the problem of illegal discharges by enterprises requires narrowing the cost difference between strict supervision by the Ministry of Environmental Protection and strict supervision by the Ministry of Environmental Protection, increasing the amount of incentives for environmental protection personnel, the higher level of government should increase the

punishment for regulatory problems in the environmental protection department, and the government should increase the punishment for illegal discharges by enterprises.

5 Conclusion

From the results of the game model analysis, the improvement of the problem of illegal discharge by enterprises should be analysed through the two perspectives of the government environmental protection departments and the discharge enterprises themselves. The cost difference between strict and non-strict regulation by the government environmental protection department is the key to the quality of environmental protection department's regulation, the punishment strength of the enterprise's non-compliance with the sewage discharge behaviour is an important influence on the enterprise's self-control, and the reasonable internal reward mechanism of the government is the key to achieve efficient environmental protection regulation. From the perspective of enterprises, the factors that have an important influence on their sewage discharge decisions are the penalties they face when their sewage discharge violations are detected, and the internal constraints they face are the high cost of their sewage discharge violations. In the following, suggestions and improvements are made to the existing problems of emissions regulation:

The State should train and provide more professional personnel for environmental protection departments to supervise corporate sewage disposal, provide more advanced sewage detection equipment and inspection funds, increase the efficiency of environmental protection departments in detecting corporate sewage disposal problems in the field, reduce the human and material costs of strict supervision by environmental protection departments, and promote the transformation of environmental protection departments into more information-based departments.

The higher authorities should establish a perfect incentive and punishment mechanism for the environmental protection sector. Increase the amount of subsidies and rewards for employees of the environmental protection department with excellent performance, to enhance the initiative and motivation of the employees in the department, and to actively invest in their working hours and reduce their leisure time. Superiors should continue to strengthen the environmental protection department internal integrity training, staff should be video records of the process, test data should be sent in a timely manner, to simplify the data review process, and actively combat corruption, and unfavourable staff to carry out severe penalties and ideological education.

The environmental protection department should increase the supervision and punishment of enterprises' illegal sewage behaviour. Government departments for sewage enterprises to carry out regular high-quality pollution testing, reduce the autonomy of the right of enterprises to discharge, increase the frequency of monitoring of corporate sewage data, for problematic data need to be timely feedback to the higher level, and in a short period of time to quickly allow enterprises to complete the rectification. For the violation of sewage enterprises to carry out large fines, and suspension of rectification, popularisation of sewage enterprises for environmental protection law-related knowledge.

The internal management of enterprises needs to establish a reasonable regulatory mechanism. Enterprises need to invest a certain amount of money to equip professional environmental protection experts, invest in professional sewage testing equipment, equipped with professional testing personnel, and develop a strict regulatory system. Enterprises need to popularise environmental protection related laws to increase the internal staff environmental awareness and environmental protection morality, increase the staff norms to detect and discharge pollutants consciously.

Enterprise pollution data need to establish a transparent process. Enterprise pollution data and costs for the outside world need to be very strong hidden, the state should formulate

relevant regulations, according to the size of the division of sewage enterprises, unified sewage enterprise pollution emission data reporting process, the whole process should be subject to video monitoring and personnel records, reduce the cost of supervision of environmental protection departments. Regularly send environmental protection department personnel to carry out monthly spot checks and tests, shorten the enterprise data upload period, increase the economic penalties for non-compliance with the enterprise to produce a strong deterrent effect on the enterprise. Illegal emissions behaviour not only causes serious negative externalities, but also affects the quality of economic development. It is believed that under the triple control of the government's environmental protection department, the higher authorities' supervision of the environmental protection department and the enterprises' own active and conscious supervision, the problem of enterprises' illegal sewage discharge will be well improved in the future.

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