



Game Theory Planning Model and Analysis of Corporate Pollution Behavior Governance

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Abstract

The hypothesis of "economic man", which is put forward by the managerial economics, has some limitations. The root of the pollution lies in the pursuit of maximization economic benefit. Based on the hypothesis of "economic man", the paper puts forward the hypothesis of "ecological man". At the same time, established game model of enterprise pollution behavior governance under two hypotheses, which is "economic man" and the "ecological man", through comparative analysis, we found that the "ecological man" hypothesis is the supplement and optimization of the hypothesis of "economic man", the pollution of enterprises can effectively solve under the assumption of "ecological man".

Keywords: *Economic man, Ecological man, Pollution control, Game theory analysis*

1. Introduction

Since the industrial revolution, mankind has created enormous wealth unmatched by any previous era, yet the rapid economic development has also brought about serious environmental pollution and ecological damage such as climate warming, ozone layer destruction, acid rain spreading, ocean red tide and other serious problems.^[7] How to treat nature correctly, how to ensure the sustainable development of society, and how to ensure the sequential evolution of social civilization, of which the quality of human beings is a crucial factor. At present, most of the analyses of environmental pollution problems at home and abroad focus on economic perspectives such as economic growth, industrial structure, urbanization, foreign trade, and government environmental management perspectives such as environmental regulations, environmental technology, and government environmental investment, but this directly ignores the assumption of "rational economic man" in economics, and disassociates from the "economic" principle of enterprises pursuing profit maximization. This directly ignores the assumption of "rational economic man" in economics, and is detached from the "economic man" nature of enterprises to pursue profit maximization.^[8] Therefore, we believe that the inherent root cause of environmental pollution problems is the enterprise's goal of maximizing economic profit, and we try to overcome

the shortcomings of the traditional "rational economic man" hypothesis by proposing the "ecological man" hypothesis. By proposing the "ecological man" hypothesis, we try to overcome the shortcomings of the traditional "rational economic man" hypothesis, that is, only when enterprises shift from "economic man", who simply pursues economic interests, to "ecological man", who pursues a combination of ecological and economic goals, can they achieve a real ecological transformation of their behavior and promote The purpose of this paper is to examine the existing ecological and economic objectives of enterprises. Therefore, the research in this paper aims to make a useful theoretical supplement to the analysis of the existing pollution problems, and its ultimate goal is to explore a new path for the solution of the pollution management problem.

2. From "economic man" to "ecological man"

2.1. Basic features and historical defects of the "economic man" hypothesis

General basic assumptions are the foundation of economic research. From the viewpoint of economic facts and their historical processes, different assumptions of economics originate from different philosophical views and methodologies, and these philosophical views and methodologies constitute the logical starting point of

the system of economic theories and related theoretical analyses. The assumptions of economics about human beings are not static, they are either generalized by observation of practice or artificially set for the convenience of building theoretical systems, and are a process of gradual development and refinement. However, it is the degree of conformity with reality and the ability to interpret history as well as the foreseeability of economic and social development that determine the scientific validity and vitality of these assumptions.

Adam Smith, the founder of classical economics, put forward the hypothesis of "economic man", who is self-interested and motivated by self-interest, as a producer, he wants to maximize profit by producing products at the lowest cost of production; as a consumer, he wants to maximize utility within as a consumer, he wants to maximize utility under the limit of expenditure; as a factor owner, he wants to provide the factor to the highest bidder to maximize the reward. At this point, the self-interest nature of the "economic man" develops into the maximization principle. However, the assumption of "economic man" makes traditional economics implicitly develop the idea of "personal interest" in the process of development, which leads to the inability of traditional economics to eliminate its inherent contradiction, i.e., to attribute the creation of market miracles to egoistic motives, even without distinguishing. It does not even distinguish between egoism, which is detrimental to others, and altruism, which is achieved through altruistic behavior by relying on the market. This makes traditional economics fundamentally theoretically limited, which is reflected in the anthropocentric value of conquering nature, and in practice, in the growing ecological crisis caused by human beings themselves. It is not difficult to understand that when the assumption of "economic man" prevails in the whole market economy, enterprises pursuing profit maximization will consider their own interests and throw the problem of environmental pollution to the society, thus bringing the serious problem of environmental pollution and ecological damage.

Therefore, we need to critically analyze the "economic man" hypothesis. It is a product of certain historical conditions, which reflects the basic characteristics of human economic behavior in a commodity society and has objectivity in a market economy, and to a certain extent it solves the difficulties brought by uncertainty and complexity to economic research. It also to a certain extent solves the difficulties brought by uncertainty and complexity to the study of economics and makes the scientific economic analysis possible.^[3] However, it has its own insurmountable limitations, and there is an urgent need for a new definition of the nature of the subject of economic behavior, a new hypothesis based on the historical logic of the hypothesis of economic man and the relationship between ecological environment and human activities, and the exploration of the law of behavior. "This may

bring economics to a new stage of development.

2.2. The logical starting point and analytical basis of the "ecological human" hypothesis

"The concept of "eco-human" is aimed at "rational economic man", which is the result of the real social and economic situation and the requirements of sustainable human development. It aims to overcome the irreparable defects of the "economic man" assumption and establish a new value judgment standard that is not only conducive to the comprehensive development of human beings but also to the sustainable development of human society, so as to change some unreasonable behaviors of enterprises. According to Xu Songling, an "ecological person" should have a double quality, not only an adequate ecological ethics, but also the ecological knowledge corresponding to his or her professional activities and life style. First of all, we know that all human activities, including economic activities, benefit from and are constrained by the ecosystem from the beginning to the end, but at different stages of development, the dominant factors governing economic and social development are not exactly the same.^[2] In times of low productivity and low population, natural capital was relatively abundant and it was man-made capital that was scarce. However, as productivity levels continue to rise and resources continue to be consumed, natural capital becomes increasingly scarce and becomes the dominant factor limiting human social development. The ecosystem can maintain a dynamic self-balance through the process of material circulation, energy conversion and system evolution, and enter a self-regulating and stable state when the dynamic evolution reaches a certain level. However, the negative externalities of the environment are becoming more and more serious as enterprises pursue the maximization of individual interests, which destroys the internal balance of the ecosystem. Second, sustainable development requires us to consider not only the interests of the present generation, but also to leave enough space for future generations to develop, so the allocation of resources is not only a short-term allocation, but also a long-term intergenerational allocation, which requires the present generation to restrain or reduce current consumption for the needs of future generations. This requires the current generation to restrain or reduce the current consumption for the needs of future generations, but it is difficult for the "economic man" who pursues the maximization of individual interests to take this responsibility.^[1] Finally, at different stages of development, the dominant indicators for measuring residents' quality of life are not static. In the era of low productivity and lack of material resources, the public focused on the scarcity of material goods and paid limited attention to the ecological environment. However, with the increase of productivity and the development of production technology, the material goods have been greatly enriched, and the ecological environment has

become one of the leading indicators for the public to measure their own quality of life.^[5] This has created a contradiction between the public's pursuit of maximizing the utility of the ecological environment and the enterprises' pursuit of maximizing economic utility, which is difficult to be solved by the traditional "economic man" assumption.

The "ecological human" hypothesis is a fundamental change and new development in the understanding of human nature in economics, which breaks through the limitations of the traditional economics hypothesis of "economic human" and makes a significant revision to the "economic human" hypothesis. "It proposes that human beings benefit from both the economic system and the ecosystem, and even more from the coordination of the two. They value not only the life of individuals, but also care about the continuity of populations; for them, money is value, and so is the ecological environment; the welfare of the present generation should be safeguarded, and the welfare of future generations should not be neglected. Ecological human" is the unified embodiment of human sociality and naturalness, and is the comprehensive embodiment of the relationship between human beings and human nature. This hypothesis provides an ideological guarantee for the change of the concept of market economy, and also provides a possibility to solve the contradiction between the pursuit of ecological and environmental utility by residents and the pursuit of economic utility by enterprises.

3. Game analysis of enterprise pollution management behavior under the assumption of "ecological human"

In order to analyze the pollution management problem of "eco-man" enterprises, we need to analyze the game of pollution management behavior of enterprises under the assumption of "eco-man" before we conduct the game analysis of traditional "economic man". In order to analyze the pollution management behavior of enterprises under the assumption of "eco-man", it is necessary to analyze the game argument of the traditional "economic man", i.e., to establish the game model of pollution management of enterprises under the assumption of "economic man" and "eco-man" respectively, and to explain the problem through comparative analysis.

3.1. Game analysis of corporate emission management behavior under the assumption of "economic man"

3.1.1. The assumptions of the model and the establishment of the game payoff matrix

The game model under the assumption of "economic man" is built under certain assumptions, and the

assumptions are as follows. i) It is assumed that there is only one enterprise in the economic life (all enterprises can be regarded as one big enterprise), and the public affected by the enterprise's emission is regarded as a whole, i.e., the two sides of the game are the enterprise and the public. ii) In the game between enterprises and the public, the enterprises have two strategic choices to control or not to control pollution, while the public has two strategic choices to resist (mainly by legal means) and acquiesce.^[9] iii) Assuming that the public will be found to be polluting as long as they resolutely resist, the public will have to pay a certain compensation to the public, assuming that both sides of the game have full knowledge of each other's benefits, i.e., the information of the participants in the basic model is complete. iv) Assume that the investment cost of emission technology and equipment, etc. incurred by the enterprise for pollution control is C_1 , and the cost of emission incurred by the enterprise for not conducting pollution control is C_2 , $C_1 > C_2$. The cost for the public to resist the polluting behavior is C_3 ; the cost for the public to acquiesce to the polluting behavior is C_4 and $C_3 > C_4$. When the company chooses to treat the pollution before releasing it, the legal compensation that the public can get by boycotting is V_1 , and when the company chooses to release the pollution directly without treating it, the legal compensation that the public can get by boycotting is V_2 and $V_1 < V_2$.

Therefore, the payoff matrix of the corporate and public game can be established, as shown in Table 3-1.

Table 1 Benefit matrix of the game between the firm and the public under the assumption of "economic man"

Public	Enterprise	
	No governance	Governance
Resist	$(V_2 - C_3, -V_2 - C_2)$	$(V_1 - C_3, -V_1 - C_1)$
acquiescence	$(-V_2 - C_4, -C_2)$	$(-V_1 - C_4, -C_1)$

Assuming that the public chooses the strategy of acquiescence ($2V_1 < C_3 - C_4, 2V_2 < C_3 - C_4$) at this time, from the perspective of the enterprise, due to $-C_2 > -C_1$, so the enterprise must choose not to govern the pollution out of the perspective of tendency to profit, that is, the equilibrium strategy is (acquiescence, no governance).

Assuming that the public chooses the strategy of boycott ($2V_1 > C_3 - C_4, 2V_2 > C_3 - C_4$) at this time, from the perspective of the enterprise, the enterprise will face two choices considering both the compensation amount as well as the cost: if the enterprise's cost of treating pollution plus the compensation amount paid is greater than the cost plus the compensation amount if the pollution is not treated, i.e. $-V_2 - C_2 > -V_1 - C_1$.

The enterprise chooses not to treat pollution pollution,

i.e., the equilibrium strategy at this time is (boycott, no treatment); conversely, the enterprise chooses the strategy of governing pollution, i.e., the equilibrium strategy is (resist, govern).

It is obvious that the choice of the firm is closely related to the behavior and reaction of the public. It shows that there is no pure strategy Nash equilibrium in this game model, but only mixed strategy Nash equilibrium.

3.1.2. solving the Nash equilibrium of the mixed strategy of the game model

① Given a probability of public boycott of q_1 , calculate the expected benefits when the firm chooses not to treat the pollution and when the firm treats the pollution, respectively, where $p_1 = 1$ when the firm does not treat and $p_1 = 0$ when the firm treats. Thus, we have.

$$U(q_1, 1) = (-V_2 - C_2)q_1 - C_2(1 - q_1) \quad (1)$$

$$U(q_1, 0) = (-V_1 - C_1)q_1 - C_1(1 - q_1) \quad (2)$$

When $U(q_1, 1) = U(q_1, 0)$, $q_1^* = (C_2 - C_1)/(V_1 - V_2)$ At this point, the expected benefits of a firm choosing to treat pollution and not treating pollution are the same, that is, when the probability of the public choosing to boycott is q_1^* , then the optimal strategy for the firm at this point is to not treat pollution, or possibly to treat pollution.

When $U(q_1, 1) > U(q_1, 0)$, $q_1 < q_1^*$, at this point, the expected benefit of the firm choosing not to treat the pollution is greater than the expected benefit of treating the pollution, that is, when the probability of the public choosing to boycott is less than q_1^* , then the optimal strategy for the firm at this point is not to treat the pollution.

When $U(q_1, 1) < U(q_1, 0)$, $q_1 > q_1^*$, at this point, the expected benefit of the firm choosing not to treat the pollution is greater than the expected benefit of treating the pollution, that is, when the probability of the public choosing to boycott is greater than q_1^* , then the optimal strategy for the firm at this point is to treat the pollution.

② Given a probability of corporate non-governance of p_1 , calculate the expected benefits of public choice of boycott and acquiescence, respectively, where $q_1 = 1$ for public boycott and $q_1 = 0$ for public acquiescence. Thus, we have.

$$U(1, p_1) = (V_2 - C_3)p_1 + (V_1 - C_3)(1 - p_1) \quad (3)$$

$$U(0, p_1) = (-V_2 - C_4)p_1 + (-V_1 - C_4)(1 - p_1) \quad (4)$$

When $U(1, p_1) = U(0, p_1)$, $p_1^* = (2V_1 + C_4 - C_3)/2(V_1 - V_2)$. At this point, the expected benefits of the public choosing to boycott and acquiesce are the same, which means that when the probability that the firm chooses not to treat the pollution is p_1^* , then the optimal strategy for the public at this point is to boycott and

possibly acquiesce.

When $U(1, p_1) > U(0, p_1)$, $p_1 > p_1^*$, at this point, the expected benefit of the public choosing to boycott is greater than the expected benefit of acquiescence, i.e., when the probability of the firm choosing not to treat the pollution is greater than p_1^* , then the optimal strategy for the public at this point is to boycott.

When $U(1, p_1) < U(0, p_1)$, $p_1 < p_1^*$, at this point, the expected benefit of the public choosing to boycott is less than the expected benefit of acquiescence, that is, when the probability of the firm choosing not to treat the pollution is less than p_1^* , then the optimal strategy for the public at this point is acquiescence.

In summary, the mixed strategy Nash equilibrium of this game model is.

$$(q_1^*, p_1^*) = \frac{C_2 - C_1}{V_1 - V_2}, (2V_1 + C_4 - C_3)/2(V_1 - V_2) \quad (5)$$

From this equilibrium solution, we can conclude that when the firm believes that the probability of public boycott is q_1^* , the probability that the firm chooses not to control pollution is p_1^* ; conversely, when the public believes that the probability that the firm does not control pollution is p_1^* , the probability that the public optimally chooses to boycott is q_1^* .

3.2. Analysis of enterprises' emission management behavior under the assumption of "ecological human"

3.2.1. The assumptions of the model and the establishment of the game payoff matrix

The game analysis of enterprise pollution control under the assumption of "ecological man" is basically the same as the assumption of "economic man". The difference is that under the "eco-human" hypothesis, the profit of the enterprise is not only profit, but also the ecological benefit of the ecological environment.^[6] The eco-efficiency index is represented by E , which is based on the WBCSD definition of eco-efficiency index, $E = \pi/I$, where π is the value of product or service index, and I is the environmental load index. The eco-benefit of pollution control is E_1 , and the eco-benefit of pollution control is E_2 and $E_1 > E_2$.^[4]

At this point, the game payoff matrix established between the firm and the public is shown in Table 2 below.

Table 2 Benefit matrix of the game between the company and the public under the assumption of "eco-people"

Public	Enterprise	
	No governance	Governance
Resist	$(V_2 - C_3, E_2 - V_2 - C_2)$	$(V_1 - C_3, E_1 - V_1 - C_1)$

acquiescenc e	$(-V_2 - C_4, E_2 - C_2)$	$(V_1 - C_4, E_1 - C_1)$
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Assuming that the public chooses the strategy of acquiescence ($2V_1 < C_3 - C_4$, $2V_2 < C_3 - C_4$), from the perspective of enterprises, enterprises will combine the ecological benefits and the costs of emissions, and face two choices: if the ecological benefits minus the costs of pollution control are smaller than the ecological benefits minus the costs of pollution control, i.e., $E_1 - C_1 < E_2 - C_2$, enterprises will choose the strategy of no control, i.e., (acquiescence, no control); conversely, enterprises will choose the strategy of control, i.e., (acquiescence, no control). enterprises will choose the strategy of governance, i.e., (acquiescence, governance).

Assuming that the public chooses the strategy of boycott, i.e., $2V_1 > C_3 - C_4$, $2V_2 > C_3 - C_4$, at this time, from the perspective of enterprises, enterprises will combine the ecological benefits, the amount of compensation and costs, and face two choices: if the ecological benefits generated by the enterprise to treat pollution minus the compensation and sewage costs are smaller than the ecological benefits generated by the enterprise not to treat pollution minus the compensation and sewage costs, i.e., $E_1 - V_1 - C_1 < E_2 - V_2 - C_2$, enterprises will choose the strategy of no treatment, i.e., (boycott, no governance); conversely, the firm will choose the strategy of governance, i.e., (resist, governance).

3.2.2. Solving the Nash equilibrium of the mixed strategy of the game model

Given a probability of public boycott of q_2 , calculate the expected benefits when the firm chooses not to treat the pollution and when the firm treats the pollution, respectively, where $p_2 = 1$ when the firm does not treat and $p_2 = 0$ when the firm treats. Thus, we have.

$$U(q_2, 1) = (E_2 - V_2 - C_2)q_2 + (E_2 - C_2)(1 - q_2) \quad (6)$$

$$U(q_2, 0) = (E_1 - V_1 - C_1)q_2 + (E_1 - C_1)(1 - q_2) \quad (7)$$

When $U(q_2, 1) = U(q_2, 0)$, $q_2^* = [(C_2 - C_1) - (E_2 - E_1)] / (V_1 - V_2)$, at this time, the expected benefits of a firm choosing to treat pollution and not treating pollution are the same, that is, when the probability of the public choosing to boycott is q_2^* , then the optimal strategy for the firm at this time is to not treat pollution, or possibly to treat pollution.

When $U(q_1, 1) > U(q_1, 0)$, $q_1 < q_1^*$, at this point, the expected benefit of the firm choosing not to treat the pollution is greater than the expected benefit of treating the pollution, that is, when the probability of the public choosing to boycott is less than q_2^* , then the optimal strategy for the firm at this point is not to treat the pollution.

When $U(q_1, 1) < U(q_1, 0)$, $q_1 > q_1^*$, at this point,

the expected benefit of the firm choosing not to treat the pollution is greater than the expected benefit of treating the pollution, that is, when the probability of the public choosing to boycott is greater than q_2^* , then the optimal strategy for the firm at this point is to treat the pollution.

When the probability of a firm not being governed is given as p_2 , the results under the "ecological man" assumption are the same as those under the "economic man" assumption. That is, $p_2^* = (2V_1 + C_4 - C_3) / 2(V_1 - V_2)$.

In summary, the mixed strategy Nash equilibrium of this game model is.

$$(q_2^*, p_2^*) = \left(\frac{[(C_2 - C_1) - (E_2 - E_1)]}{V_1 - V_2}, (2V_1 + C_4 - C_3) / 2(V_1 - V_2) \right) \quad (8)$$

From this equilibrium solution, we can conclude that when the firm believes that the probability of public boycott is q_2^* , the probability that the firm chooses not to control pollution is p_2^* ; conversely, when the public believes that the probability that the firm does not control pollution is p_2^* , the public's optimal choice of boycott probability is q_2^* .

4. Conclusion

Through the previous game analysis, the comparison results can be found that the two present some common features, but of course there are also significant differences.

4.1. The same characteristics under the two different assumptions are manifested in the following aspects

First, if the probability that a firm does not control pollution is p , the expected benefits to the public (resistance and acquiescence strategies) are the same under the "ecological man" scenario as under the "economic man" scenario. That is.

$$U_1(1, p) = U_2(1, p) = (V_2 - C_3)p + (V_1 - C_3)(1 - p) \quad (9)$$

$$U_1(0, p) = U_2(0, p) = (-V_2 - C_4)p + (-V_1 - C_4)(1 - p) \quad (10)$$

At the same time, the equilibrium solution $p^* = p_1^* = p_2^* = (2V_1 + C_4 - C_3) / 2(V_1 - V_2)$ shows that the probability range of not treating pollution is $(0, p^*)$ for both "economic" and "ecological" enterprises, where the value of p^* is related to V_1 , V_2 , C_3 and C_4 . Therefore, the probability range of not treating pollution can be reduced by changing the size of V_1 , V_2 , C_3 and C_4 . The range of probability that an enterprise does not control pollution can be narrowed by changing the size of V_1 , V_2 , C_3 and C_4 .

Second, the magnitude of the expected benefits

(pollution control strategy vs. no pollution control strategy) under both the "economic man" and "ecological man" scenarios is correlated with the probability of the public choosing the boycott strategy q .

$$q_1^* = C_2 - C_1 / V_1 - V_2 \quad (11)$$

$$q_2^* = [(C_2 - C_1) - (E_2 - E_1)] / V_1 - V_2 \quad (12)$$

It can be seen that the values of $C_2 - C_1$ and $V_1 - V_2$ affect the values of q_1^* and q_2^* , i.e., the difference between the cost of pollution control and the cost of not controlling pollution, and the difference between the amount of compensation the company has to pay to the public for controlling pollution and not controlling pollution affects the probability of the public choosing the boycott strategy q , which in turn affects the expected revenue of the company. Therefore, by changing the magnitude of $C_2 - C_1$ and $V_1 - V_2$, the probability of the public choosing the boycott strategy can be changed to increase the expected revenue of the firm.

Obviously, these same features under the assumptions of "economic man" and "ecological man" above, to a certain extent, corroborate that the assumption of "ecological man" is not a total negation of the assumption of "economic man". The "economic man" hypothesis is not a total negation of the "economic man" hypothesis, but a useful supplement and improvement of the "economic man" based on the "economic man".

4.2. The differences under the two different assumptions are mainly in the following aspects.

Firstly, in the case of public $C_1 > C_2$ acquiescence, the "economist" companies will only consider the cost factor to decide whether or not to control the pollution. As long as the residents choose to acquiesce to the strategy, the "economist" enterprises will not control the pollution. On the other hand, the "eco-people" enterprises will choose whether to control pollution discharge or not based on the comparison of ecological benefits and costs, and if $E_1 - C_1 < E_2 - C_2$, they will consciously adopt pollution control behavior.

Second, under the assumption of "economic man", when the probability of the public choosing to boycott q is greater than q_1^* , i.e., $q > q_1^*$, the optimal choice strategy for the enterprise is to control pollution; under the assumption of "ecological man", when the probability of the public choosing to boycott q is greater than q_2^* , i.e., $q > q_2^*$, the enterprise will choose to control pollution. $q_2^* < q_1^*$ The lower bound of the probability of public boycott under the "ecological human" assumption is lower than that under the "economic human" assumption, i.e., the requirement of public boycott is more lenient and easier to achieve.

Therefore, when the probability of public boycott increases, "eco-human" enterprises choose to control pollution first than "economic" enterprises. In this way, the public plays a more significant role under the "eco-people" hypothesis.

In addition, in the previous analysis, it can be seen that many indicators are related to eco-efficiency E_1 and E_2 , while the magnitude of E_1 and E_2 depends on the government's accounting and regulation of the environmental burden index I , and the government can effectively regulate the pollution control behavior of enterprises through the mobilization of I . In this way, the government can play its initiative more effectively under the assumption of "eco-man".

From the above difference analysis, we can see that compared with the conditions under the "economic man" hypothesis, the conditions of pollution control for enterprises under the "ecological man" hypothesis are much more relaxed, indicating that the "ecological man" hypothesis is a further optimization of the "economic man" hypothesis in terms of pollution control for enterprises. The "eco-man" hypothesis is a further optimization of the "economic man" hypothesis.

In short, we can clearly conclude that the pollution control of "eco-man" enterprises is more in line with the requirements of sustainable and coordinated economic and environmental development. "The profit maximization goal of "economic man" is the root cause of the pollution behavior of enterprises.", the problem of pollution control can be fundamentally solved.

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