

# Study on the Influence of Emission on Enterprise's Carbon Emission Reduction Decisions Considering Public Participation

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## Abstract

Public participation in the carbon emission reduction is an important part of the construction of social ecological civilization, which has a significant impact on enterprise decision-making. At the same time, enterprises decision-making is also affected by the emotion of the carbon emission reduction. It is of practical significance to analyze the influence of different emotions on enterprise's carbon emission reduction decision-making considering public participation. Taking emotion as the main parameter of the game model, the public and enterprises are set as the main body of the carbon emission reduction, the influence of rational emotion, optimism and pessimism on the evolution path of the carbon emission reduction. The results show that the decision-making of carbon emission reduction is mainly influenced by public emotion, and the probability of the carbon emission reduction increases with the rise of public participation, but it is less influenced by self-sentiment. When the enterprises optimism parameter is high, the public chooses not to participate in the carbon reduction.

**Keywords:** *carbon emission reduction; public participation; emotional influence; rank dependent expected utility*

## 1. INTRODUCTION

With the rapid development of the economy, energy consumption keeps rising. However, the use of fossil fuels brings about a series of environmental problems, which are harmful to public health. As environmental problems become more and more prominent, reducing environmental pollution and carbon emission reduction become a difficult problem to be solved urgently. The main body of the carbon emission reduction includes the public, enterprises and governments. On August 7, 2018, the environmental impact assessment issued by the Ministry of Ecology and environment defines the role of public participation in environmental behavior<sup>[1]</sup>. Many developed countries derive more than a third of their carbon emission from energy consumption and private use, so the public plays an important role in low carbon sustainability<sup>[2]</sup>. Jia<sup>[3]</sup> believed that all circles should listen to public opinion in an open manner, gradually deploy, and make clear the impact of public participation on corporate carbon emission reduction decision-making<sup>[4]</sup>.

The emotional response of humans to carbon emission reduction and climate change can potentially affect their low carbon behavior<sup>[5]</sup>. For example, after the implementation of the carbon emission reduction, global carbon emissions in 2014 for the first time to achieve zero growth, leading to public optimism about carbon emission reduction, believe that through carbon emission reduction can reduce environmental problems, actively adopt a series of low-carbon behavior. On the contrary, pessimism is likely to reduce the public's expectations of the utility of the carbon emission reduction actions, and thus no carbon emission reduction activities. From the economic point of view, domestic and foreign scholars analyze how participants' emotional reaction to carbon emission reduction and climate change affects their carbon emission reduction behavior. The results show that emotion interferes with people's behavior decision-making by influencing people's expectation benefit and psychological distance<sup>[6]</sup>. The research on the influence of emotion on human behavior has been extended from the original psychology to many fields such as society and economy. Based on the rank dependent expected utility, a group conflict game model is constructed, and

the existence of Game Nash Equilibrium in different emotional states is discussed<sup>[7]</sup>. Hornsey<sup>[8]</sup> organized 431 volunteers to read neutral, optimistic, and pessimistic information about global progress in reducing carbon emission, and then recorded their low-carbon behavior. The study found that participants were more likely to be optimistic about the environment than pessimistic. Different emotional intensity not only changes the final result of evolution, but also affects the speed of evolution of group decision-making<sup>[9]</sup>.

Existing researches on the carbon emission reduction focus more on the influence of emotion on government and business decision-making, and neglect the role of public participation. Therefore, this paper introduces the emotional parameter, constructs the public participation enterprises carbon emission reduction decision-making model, determine its evolution game strategy, and obtains the emotion influence to the enterprise decision-making through the numerical analysis emotional parameter sensitivity.

## 2. CONSTRUCTION OF CARBON EMISSION REDUCTION MODEL UNDER DIFFERENT EMOTIONS

### 2.1. Carbon emission reduction model construction

This paper mainly constructs the enterprise  $B$  and the public  $P$  as two subjects, and studies the carbon emission reduction decisions under different public and enterprise emotions without considering other influencing factors. As the CO<sub>2</sub> emitted by enterprises causes the public to suffer environmental losses  $L$ , the cost of public participation in the carbon emission reduction activities with the enhancement of environmental awareness is  $C_1$ , and if companies reduce their carbon emissions, the public gets a subsidy  $\pi$ ; The cost of the carbon emission reduction is  $C_2$ , the benefit is  $V_1$ , the additional benefit is  $B$ , if the public participates in the carbon emission reduction; the benefit is  $V_2$ , if the public participates in the carbon emission reduction, the enterprises suffer a reputational loss  $F$ . Suppose the probability of the carbon emission reduction is  $x$ , the probability of no carbon emission reduction is  $1-x$ , the probability of public participation is  $y$ , the probability of no participation is  $1-y$ . The game matrix is shown in Table 1.

**TABLE 1** PUBLIC AND CORPORATE CARBON REDUCTION DECISIONS

e	Enterprises( $E$ )	
	carbon emission	not carbon emission

		reduction ( $x$ )	reduction ( $1-x$ )
Public ( $P$ )	Participation ( $y$ )	$V_1 + B - C_2$	$V_2 - F$
		$\pi - C_1$	$-C_1 - L$
	non-participation ( $1-y$ )	$V_1 - C_2$	$V_2$
		0	$-L$

### 2.2. Carbon emission reduction model under emotional parameters

Using rank dependent expected utility of grade dependence to better represent the carbon emission reduction decision of enterprises and the public under different emotions. As can be seen above, the benefits of the public and enterprises under different choices, and the ranking of the relationship between enterprises benefits is  $V_1 - C_2 + B > V_2 > V_1 - C_2 > V_2 - F$ , the ranking of the relationship between public benefits is  $\pi - C_1 > 0 > -L > -L - C_1$ . Assume that the emotion parameter  $r$  meets: When  $r = 1$ , the player has no emotion; When  $r > 1$ , the players are optimistic; When  $0 < r < 1$ , the players are pessimistic. Due to public participation in carbon reduction,  $r_2 > 1$ . The utility level and decision weight of each benefit of the enterprise and the public are calculated, as shown in Table 2 and Table 3.

**TABLE 2** THE ENTERPRISE INCOME UTILITY LEVEL AND DECISION WEIGHT CONSIDERING EMOTION

utility	probability	utility level	decision weight
$V_1 + B - C_2$	$xy$	1	$\omega_1(xy)$
$V_2$	$(1-x)(1-y)$	$1-x$	$\omega_1(1-x-y+2xy) - \omega_1(x)$
$V_1 - C_2$	$x(1-y)$	$x+y-2xy$	$\omega_1(1-y+xy) - \omega_1(1-x-y+2xy)$
$V_2 - F$	$(1-x)y$	$y-xy$	$1 - \omega_1(1-y+xy)$

**TABLE 3** THE PUBLIC INCOME UTILITY LEVEL AND DECISION WEIGHT CONSIDERING EMOTION

utility	probability	utility level	decision weight
$\pi - C_1$	$xy$	1	$\omega_1(xy)$
0	$x(1-y)$	$1-x+xy$	$\omega_1(x) - \omega_1(xy)$
$-L$	$(1-x)(1-y)$	$1-x$	$\omega_1(1-y+xy) - \omega_1(x)$
$-C_1 - L$	$(1-x)y$	$y-xy$	$1 - \omega_1(1-y+xy)$

The expected utility function dependent on the level of the carbon emission reduction by enterprises and the public are:

$$V_E = (B - C_2)(xy)^{\omega_1} + C_2(1-x-y+2xy)^{\omega_1} + (V_1 - V_2 + F - C_2)(1-y+xy)^{\omega_1} + V_2 - F \quad (1)$$

$$V_p = (\pi - C_1)(xy)^{r_2} + Lx^{r_2} + C_1(1 - y + xy)^{r_2} - C_1 - L \quad (2)$$

### 3. SOLVING CARBON EMISSION REDUCTION MODEL UNDER DIFFERENT EMOTIONS

Based on the dependence of the expected utility functions (1) and (2) on the above levels of enterprises and the public's participation in the carbon emission reduction, the partial derivatives of the probabilities  $x$  and  $y$  are respectively calculated and set to 0, so that:

$$\frac{\partial V_E}{\partial x} = r_1 y (B - C_2)(xy)^{r_1-1} + r_1(2y-1)C_2(1-x-y+2xy)^{r_1-1} + r_1 y (V_1 - V_2 + F - C_2)(1-y+xy)^{r_1-1} = 0 \quad (3)$$

$$\frac{\partial V_p}{\partial y} = r_2 x (\pi - C_1)(xy)^{r_2-1} + r_2(x-1)C_1(1-y+xy)^{r_2-1} = 0 \quad (4)$$

According to the equilibrium solution method, the solution of functions (3) and (4) is the equilibrium solution of the game between enterprises and the public. If the functions have a solution, the game has an equilibrium strategy. If the functions have no solution, there is no equilibrium strategy in the game. The following will discuss the strategic choices of enterprises and the public under different emotions.

$$\begin{cases} \frac{\partial V_E}{\partial x} = r_1 y (B - C_2) \left( \frac{xy}{1-y+xy} \right)^{r_1-1} + r_1(2y-1)C_2 \left( \frac{1-x-y+2xy}{1-y+xy} \right)^{r_1-1} + r_1 y (V_1 - V_2 + F - C_2) = 0 \\ \frac{\partial V_p}{\partial y} = r_2 x (\pi - C_1) \left( \frac{xy}{1-y+xy} \right)^{r_2-1} + r_2(x-1)C_1 = 0 \end{cases} \quad (6)$$

Because of  $xy < 1 - y + xy$  and  $1 - x - y + 2xy$ , when  $r_1, r_2 \rightarrow \infty$ ,  $\left( \frac{xy}{1-y+xy} \right)^{r_1-1}$  and  $\left( \frac{1-x-y+2xy}{1-y+xy} \right)^{r_1-1}$  tend to 0. To solve the available are  $x = 1$ ,  $y = 0$ , that is, enterprises are willing to carry out carbon emission reduction, and the public chooses not to participate.

$$\begin{cases} \frac{\partial V_E}{\partial x} = r_1 y (B - C_2) \left( \frac{1-y+xy}{xy} \right) + r_1(2y-1)C_2 \left( \frac{1-x-y+2xy}{1-x-y+2xy} \right) + r_1 y (V_1 - V_2 + F - C_2) = 0 \\ \frac{\partial V_p}{\partial y} = r_2 x (\pi - C_1) \left( \frac{xy}{1-y+xy} \right)^{r_2-1} + r_2(x-1)C_1 = 0 \end{cases} \quad (7)$$

The lower formula gets  $x = 1$ , the upper formula gets  $\frac{\partial V_E}{\partial x} = (F - C_2)y^2 + (B + C_2)y - C_2 = 0$ , when

### 3.1. Enterprise are in a rational emotion

When enterprises show rational emotion,  $r_1 = 1$ ,  $r_2 > 1$ , that is  $r_1 - 1 = 0$ ,  $r_2 - 1 \rightarrow \infty$ . The equations are transformed into:

$$\begin{cases} \frac{\partial V_E}{\partial x} = y(B - C_2) + (2y-1)C_2 + y(V_1 - V_2 + F - C_2) = 0 \\ \frac{\partial V_p}{\partial y} = r_2 x (\pi - C_1) \left( \frac{xy}{1-y+xy} \right)^{r_2-1} + r_2(x-1)C_1 = 0 \end{cases} \quad (5)$$

To solve the available are  $x = 1$ ,  $y = \frac{C_2}{V_1 - V_2 + B + F}$ . When the enterprises is in a rational emotion and the public is in an optimistic emotion, there is an equilibrium strategy between the enterprises and the public. Enterprises are willing to choose carbon emission reduction, and the public has the probability of  $\frac{C_2}{V_1 - V_2 + B + F}$  to choose to participate in the carbon emission reduction.

### 3.2. Enterprises are in an optimistic emotion

When the enterprises and the public are in an optimistic emotion,  $r_1 > 1, r_2 > 1$ , set enterprises and the public are overly optimistic,  $r_1 \rightarrow \infty$ ,  $r_2 \rightarrow \infty$ . The equations can be deformed as:

### 3.3. Enterprises are in a pessimistic emotion

When the enterprise is in a pessimistic emotion and the public is in an optimistic emotion,  $0 < r_1 < 1, r_2 > 1$ . it is assumed that the enterprise is in an overly pessimistic mood and the public is in an overly optimistic mood,  $r_1 \rightarrow 0, r_2 \rightarrow \infty$ , and the equation system is deformed as follows:

$y = 0$ ,  $\frac{\partial V_E}{\partial x} < 0$ , when  $y = 1$ ,  $\frac{\partial V_E}{\partial x} > 0$ , so there is

$y^*$ , which makes  $\frac{\partial V_E}{\partial x} = 0$ . When the company is in a negative emotion, the public is in a positive emotion,  $(1, y^*)$  is the equilibrium strategy.

#### 4. NUMERICAL ANALYSIS

In order to better demonstrate the impact of participants' emotions on corporate carbon emission reduction and public participation, numerical analysis is conducted on the above models. Suppose that the environmental loss suffered by the public  $\bar{L}$  is 2, the cost

of public participation  $C_1$  is 1, and if the enterprise carries out carbon emission reduction, the public subsidy  $\pi$  is 2; The cost of carbon emission reduction for the enterprise  $C_2$  is 3, and the benefit brought by it  $V_1$  is 10. If the public participates in the carbon emission reduction, the additional benefit  $B$  is 1.5. If the public participates in the carbon emission reduction at this time, the profit of the enterprise  $V_2$  is 8, and the reputation loss of the enterprise  $F$  is 1.5. The results of the evolutionary game are shown in the figure below, where the solid line represents function (3) and the dashed line represents function (4).

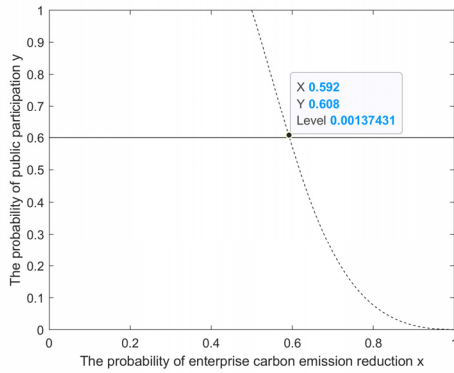


Fig.1(a)  $r_1 = 1, r_2 = 1.5$

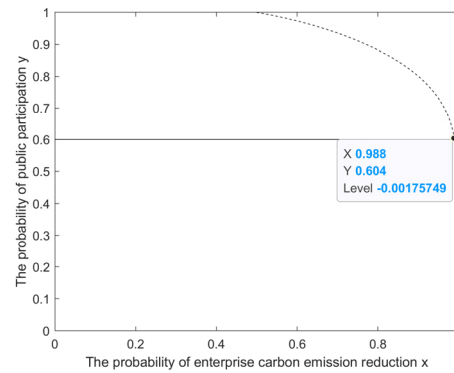


Fig.1(b)  $r_1 = 1, r_2 = 10$

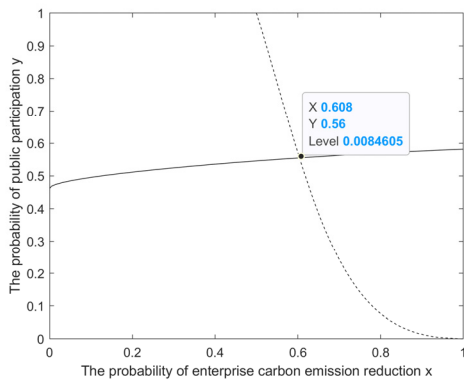


Fig.1(c)  $r_1 = 1.5, r_2 = 1.5$

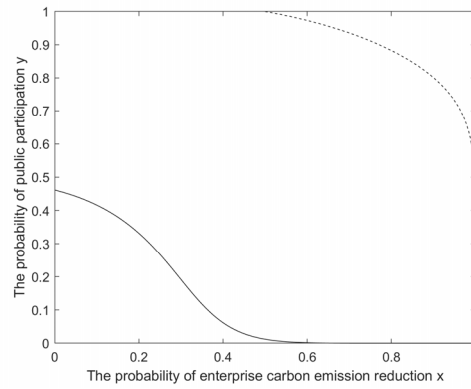


Fig.1(d)  $r_1 = 10, r_2 = 10$

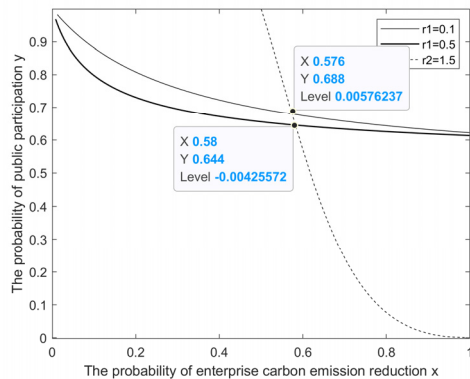


Fig.1(e)  $r_2 = 1.5$

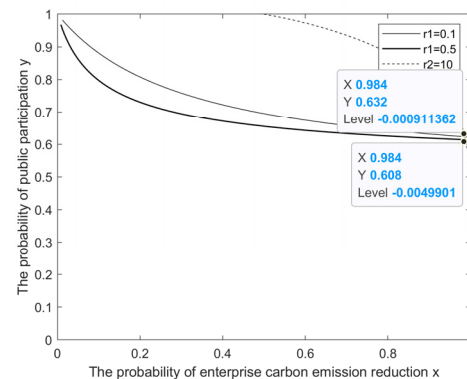


Fig.1(f)  $r_2 = 10$

Fig. 1 carbon emission reduction decisions of enterprises and the public under different emotions

It can be seen from the Fig.1 that in the initial state, the public has a high enthusiasm to participate in the carbon emission reduction and is optimistic about carbon emission reduction. However, in a rational emotion, enterprises' willingness to reduce carbon emission increases with the rise of public participation. As the dominant player in the carbon emission reduction market, enterprises need to consider policy orientation, market demand and interest balance when making decisions. Since consumers are optimistic about carbon emission reduction, enterprises choose to conduct carbon emission reduction. When the enterprise is in an optimistic emotion, with the rise of optimism, the willingness of the enterprise to carry out carbon emission reduction increases, and finally evolves into the willingness to carry out carbon emission reduction. However, the willingness of the public to participate in carbon emission reduction decreases with the increase of the willingness of enterprises to reduce carbon emission. When enterprises are willing to conduct carbon emission reduction, the public chooses to free riding, and does not participate in the carbon emission reduction but enjoys the loss of environmental optimization. When the enterprise is in a pessimistic emotion, the decision of the enterprise eventually evolves into the willingness to carry out carbon emission reduction, and the willingness of the enterprise to reduce carbon emission is mainly affected by the public emotion rather than its own emotion. As can be seen from the Fig.1, the change of enterprise's own emotion has little influence on the decision result.

## 5. CONCLUSION

Based on the rank dependent expected utility, this paper introduces emotion parameters to establish the carbon emission reduction decision-making model of enterprises with public participation, and studies the influence of carbon emotion on the carbon emission reduction decision-making of enterprises when the public is optimistic about the carbon emission reduction. And through numerical analysis of the enterprise under the rational, optimistic and pessimistic emotion of the carbon emission reduction decisions. The analysis shows that : (1) The carbon emission reduction decisions of enterprises are mainly affected by public emotion, and the probability of the carbon emission reduction increases with the increase of public participation emotion, but is less affected by their own emotion; (2) When both enterprises and the public are in an optimistic emotion, the public's decision eventually evolves to not participate in the carbon emission reduction as the enterprise's carbon emission reduction emotion rises. Due to the high willingness of enterprises to reduce carbon emissions, the public can enjoy the loss reduced by environmental optimization through free ride behavior, but do not pay the cost. Therefore, when the enterprises optimism parameter is high, the public chooses not to participate in the carbon emission reduction.

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