

# *How should companies act when faced with increasing levels of consumer preference on low carbon?*

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**Abstract:** With increasing consumer low-carbon preferences, firms have become motivated to proactively join carbon emission reduction initiatives. We explore the competitive and cooperative relationships between leading and following firms during the active carbon reduction phase, focusing on the effects of consumer low-carbon preferences on inter-firm competition, firm profits, and industry carbon reduction. We constructed a three-stage dynamic game model: leading and following firms decide on their competitive relationship with each other in the first stage, decide on their own carbon emission reduction in the second stage, and compete for sequential output in the third stage. It is found that, firstly, when the level of consumers' low carbon preference is too low or too high, firms choose carbon emission reduction competition relationship, and only when the level of consumers' low carbon preference is at a generally significant level, firms choose carbon emission reduction cooperation; secondly, the unit product carbon emission reduction of the leading firm is higher than the unit product carbon emission reduction of the following firm in emission reduction competition, and converges to the same level as the unit product carbon emission reduction of the following firm in emission reduction cooperation. Finally, the emission reduction cooperation can improve the industry output and industry carbon emission reduction, which is beneficial to the industry as a whole. The study provides a theoretical basis for enterprise decision making and government policy formulation.

## 1. Introduction

The rapid economic development has far exceeded the carrying capacity of the environment, and excessive greenhouse gas emissions have been followed by a series of frequent extreme climate events such as heavy rainfall, heat waves, and sustained sea level rise. Five shared socio-economic pathways (SSPs) were constructed in IPCC's sixth assessment report, which states that only the lowest emission scenarios SSPs 1-1.9 can contain global climate change to 1.5 °C range set by the Paris Agreement (IPCC, 2021)[1].

In order to reduce carbon emissions, many regulations and commitments have been made from international to national level to reduce carbon emissions (Fan, X., Chen, K., & Chen, Y. J. (2022). *Is Price Commitment a Better Solution to Control Carbon Emissions and Promote Technology Investment? Management Science.*) [2]. China, as the world's largest developing country, has pledged to peak its carbon dioxide emissions by 2030 and to become carbon neutral by 2060 in order to make a greater contribution to the global

carbon reduction efforts[3]. However, the development of a low-carbon economy requires huge investment, and some scholars have estimated that in order to achieve the goal of carbon peaking by 2030, low-carbon investment in energy industry and energy conservation should increase year by year, reaching 2.52 billion yuan in 2030; while the current scale of fund supply is about 520 billion yuan per year (Li, B. H., Chen, B., Huang, B.J. & Yin, Y. (2017). *Climate Financing Demand Analysis in China Based on CFDAM Model*. *Journal of Fudan University (Natural Science)*.) [4]. Therefore, under certain financial pressure, in addition to internalizing external costs, as the main body of carbon emission reduction, how to stimulate the motivation of enterprises to take the initiative to reduce emissions and guide them to join the ranks of carbon emission reduction without delay[5-6].

In recent years, with the introduction and application of concepts such as sharing economy and digital economy (e.g. bicycle sharing, online dating, mobile payment, etc.), their deep integration with the environmental field and technological innovation have injected new momentum into the low-carbon transformation, in which consumers' low-carbon preference level is continuously guided and stimulated, and leading companies foresee long-term or short-term gains and start to implement active emission reduction strategies to gain competitive advantage (下方 下方) [7]. For example, L'Oréal built its largest color cosmetics production base in Asia Pacific, the Tianmei factory, into a "zero-sum factory" in 2015 (下方) [8]. But for uneven market forces, the high cost of emission reductions can put SMEs at a disadvantage at the expense of current benefits, and companies need to consider how to choose their emission reduction strategies and how to enter the market to gain a greater advantage[9].

The "China Enterprise Innovation Trends Index 2017 Report" shows that fierce market competition is forcing companies to innovate, and there is a clear trend toward corporate cooperation (下方) [10-11]. A large number of scholars have also pointed out the benefits that abatement cooperation can bring to companies, such as lower production costs and increased market share (下方, 下方, 下方, 下方) [12]. As consumers' low-carbon preferences continue to grow, is emissions reduction collaboration still the best option for firms of all sizes with varying degrees of power? In this regard, we explored the following questions: (1) How do changes in the level of consumer preferences affect firms' carbon reduction and production decisions? (2) Is emissions reduction cooperation the best option for firms with uneven market power? (3) How does this choice affect firms' expected profits, their respective carbon emission reductions, and total industry carbon emissions?

To address these issues, this paper constructs a three-stage game model between leading and following firms to study the carbon reduction strategies of firms in the active reduction stage[13-14]. To maximize expected profits, firms decide whether to cooperate in emission reduction in the first stage, decide the amount of carbon reduction per unit of product in the second stage, and compete for sequential output in the third stage[15]. Based on this, we explore the carbon abatement strategies of leading and following firms in the competition and cooperation scenarios, the impact of consumer low-carbon preferences on firm profits and firm strategy choices, and the impact of consumer low-carbon preferences on industry carbon emission reductions and industry output, etc[16]. The problem is set in the context of investment decisions as a long-term strategy compared to production plans.

In summary, our contribution is mainly threefold. First, this research perspective is novel. The existing literature mainly explores firms' carbon reduction strategies from the perspective of the dual push of government regulation and consumer low-carbon preferences, narrowing down the influence of consumer low-carbon preferences, which are constantly guided and stimulated by the digital economy as well as the sharing economy, on firms' decisions, while with the increasing consumer low-carbon preferences, firms already have the motivation to actively join carbon reduction actions under the market regulation mechanism, this paper raises the awareness of the importance of

consumer low-carbon (下方, 下方) [17]. This paper raises awareness of the importance of consumers' low-carbon preferences. Second, most scholars have only discussed the case of simultaneous decisions on output, while in actual market competition, firms often face potentially disparate market power, which implies different levels of investment and technology, so this paper highlights the different choices of SMEs and leading firms under the asymmetry of market power[18]. Finally, this paper finds that the effects of different firms' decisions on their carbon emission reduction are different under different levels of consumer low-carbon preferences, and that there exists a relative interval within which the level of consumer low-carbon preferences can play a better moderating role, and also proposes targeted management recommendations on how the growth of consumer low-carbon preferences affects firms' carbon emission reduction decisions, providing policy insights for Chinese firms' digital transformation and It also provides policy implications for the digital transformation and green economic growth of Chinese enterprises.

The rest of the paper is organized as follows. We first review the relevant literature in Section II. The model and variable selection are described in Section III. The analysis and discussion of the model results are carried out in Section IV. Section V verifies the consistency of the results with a case study and some other extensions. Conclusions and management recommendations are given in Section VI

## 2. Literature Review

When we discuss the carbon emission reduction decision of enterprises, there are many factors that influence the carbon emission reduction decision of enterprises[19]. According to the relevance of the research content of this paper, previous studies focus on two aspects, on the one hand, we analyze the impact of various different government carbon emission policies on the carbon emission reduction decision of enterprises, and on the other hand, we emphasize the importance of consumers' low-carbon preferences.

A large number of scholars have already studied the impact of different carbon emission policies on enterprises' production and operation decisions, focusing on the optimal carbon emission reduction decisions of enterprises under different carbon emission policies[20]. The current policies related to carbon emissions at home and abroad are mainly divided into two types: one is the punitive measures related to carbon trading and carbon tax, and the other is the incentive measures based on subsidies. In the part of carbon tax and carbon trading, scholars analyze the game relationship between government and enterprise subjects with different roles based on the Stackelberg game framework, or compare the effects of two systems of carbon cap-and-trade and carbon tax on total carbon emissions, enterprise profits and social welfare, etc., taking consumer low-carbon preferences as a limiting factor under the two systems, ignoring the influence of consumer low-carbon preferences on enterprise decisions (下方., 下方) [21]. The influence of consumer preferences on firms' decisions is ignored (下方, 下方, 下方) [22]. The exploration of consumer low-carbon preferences is more based on the incentive measures of government subsidies, the study of enterprises' competitive emission reduction strategies and emission reduction cooperation strategies, and the consideration of the impact of consumer low-carbon preferences only, and the lack of in-depth exploration of consumer low-carbon preferences (下方, 下方 下方 下方) [23].

There is little literature analyzing firms' deduction on carbon emission from the viewpoint of participants' cooperation and competition. In fact, in addition to individual efforts to reduce carbon emissions, the general trend is for companies to seek green innovation in cooperation with their upstream and downstream supply chain partners or other companies, and that cooperation in reducing emissions can have a positive impact on the total profit, environment, and social welfare of the cooperating companies (下方) [24]. Cooperation is generally divided into vertical and horizontal

cooperation, with vertical cooperation referring to cooperation among supply chain members and horizontal cooperation referring to cooperation among competitors at the same level. The literature has studied two mechanisms of cooperation between two supply chain members in green R&D investment: cartelization and cost-sharing contracts, and found that consumer low-carbon preference is one of the important effectiveness factors, and cooperation is always beneficial to consumers and the environment compared to non-cooperation (下方) [25]. R&D cooperation can also bring other benefits to firms, such as lower production costs and increased market share (下方下方) [26].

In addition to this, our research also takes into account the issue of uneven market power. On the one hand, limited by the size of the enterprise itself, the corresponding market size is very different. On the other hand, the enterprise will complete the emission reduction target under the condition of ensuring the enterprise profit, and the product demand is vulnerable to the impact of external emergencies. Taking different emission reduction measures makes a great change in the profit and carbon emission reduction of enterprises. Existing literature is often based on the perspective of static games for output competition, that is, participants act simultaneously in the market. In actual markets, when the size of the firm is different, the news may be asymmetric. Therefore, we consider leading firms and firms. Follow the sequential competition of enterprises.

With the continuous improvement of consumers' low-carbon preference, their driving force for enterprises' carbon emission reduction is gradually increasing, and we need to pay more attention to and explore them. At the same time, the cooperation of enterprises in emission reduction can not only reduce the cost of enterprises, but also benefit consumers and the environment. This paper uses the method of sequential game to study when it is more beneficial for enterprises to cooperate in reducing emissions. At the same time, considering the factors of uneven market power, this paper is distinguished from the previous research. In addition, most papers argue that consumers' low-carbon preference can only be used as a driving factor, and often requires the blessing of other policies to influence corporate decision-making. However, in order to magnify the importance of consumers' low-carbon preferences, this paper does not combine consumers' low-carbon preferences with policies.

### 3. Model

#### 3.1. Model Description

Assuming that there are two enterprises  $B_i, i = 1, 2$  producing homogeneous products in the market which produce  $q_i$  units of products with the cost of  $c, c > 0$  per unit, so the total production quantity on market should be  $Q = q_1 + q_2$ . Considering the influence of consumers' low carbon preference, when the carbon emission reduction on per unit product of enterprise  $B_i$  is  $e_i$ , the inverse demand function for the price of a product is  $P(Q) = a - Q + me_i$  ( $a > 0$ ), while  $a$  is the market size and  $a > Q$ ,  $m$  is the low carbon preference coefficient of consumers and  $m > 0$  (下方).

Under these assumptions, the one-time emission reduction cost of enterprise  $B_i$  is  $\frac{1}{2}ye_i^2$  ( $y > 0$ ), while  $y$  is the abatement-related fixed investment cost factor, indicating the impact of abatement on costs. Then  $B_i$ 's total cost function is  $C_i = cq_i + \frac{1}{2}ye_i^2$ . Since this paper mainly explores the impact of consumers' low carbon preference on corporate carbon emission reduction decisions, it does not consider corporate emission reduction spillover effects. The profit of enterprise  $B_i$  is equal to the sales revenue minus the total production cost and the one-time emission reduction input cost:

$$\pi_i = (a - q_i - q_j + me_i)q_i - \frac{ye_i^2}{2} - cq_i, i, j = 1, 2, i \neq j \quad (1)$$

This paper considers a three-stage dynamic game with complete information symmetry between leading and following firms, emphasizing the importance of unbalanced market power. Leading

companies and follower companies are both active bearers of carbon responsibility and actively participate in carbon emission reduction actions under the regulation of market mechanisms. In the real economy, L'Oréal's Tianmei factory is a model of actively fulfilling carbon responsibility. Under the background of the double carbon goal, this paper first explores the emission reduction decision-making between leading companies and follower companies, and then explores consumers' low-carbon preference on corporate profits, carbon emission reduction per unit product, and industry carbon emission reduction. volume and industry output. The game process is described in detail as follows: in the first stage, the leading company and the follower company determine the competition and cooperation relationship between each other, and in the second stage, the two companies simultaneously determine their own carbon emission reductions. In the third stage, the two firms compete for output. The leading company first determines the output  $q_1$ , and the follower company determines  $q_2$  after observing  $q_1$ , and finally maximizes the profits of the two companies.

### 3.2. Solution of the model

This section focuses on solving the optimal carbon emission reduction decisions of leading companies and follower companies under competition and cooperation. Since the influence of the behavior of the current stage on the later stage is considered when making decisions, the reverse induction method is used to solve the problem. Multiple parameters cause difficulties in analysis and solution, and the only sufficient condition for equilibrium in this model is  $y > 0$ . Under the premise of not changing the basic properties and conclusions, this section takes  $y=2$  and  $A=1$  when drawing graphs (下方).

#### 3.2.1. The optimal carbon emission reduction decision of enterprises in the competitive model

In the third stage, enterprise  $B_i$  competes for output with known carbon emission reductions, and its profit function is expressed as:

$$\pi_i = (a - q_i - q_j + me_i)q_i - \frac{ye_i^2}{2} - cq_i, i, j = 1, 2, i \neq j \quad (2)$$

The leader company first predicts the response of the follower company to determine the output  $q_1$ :

$$\text{FOC: } q_2(q_1) = \frac{a - q_1 - c + me_2}{2} \quad (3)$$

Substitute (3) into the profit function of the leading firm to find the first derivative of its output  $q_1$ , and set  $\frac{\partial \pi_1}{\partial q_1} = 0$  to get the equilibrium output of the leading firm:

$$q_1^* = \frac{a - c - me_2 + 2me_1}{2} \quad (4)$$

Substitute (4) into (3) to obtain the equilibrium output of the following firm:

$$q_2^* = \frac{a - c + 3me_2 - 2me_1}{4} \quad (5)$$

It can be seen that the balanced output of leading companies and follower companies is not only affected by their own carbon emission reductions, but also cross-influenced by the carbon emission reductions of other companies. The carbon emission reduction of the other company will decrease with the increase of carbon emission reduction, and its own impact is greater than the cross impact.

Substitute (4) and (5) into the profit function formula (2) of the leading enterprise and the following enterprise respectively to obtain the equilibrium profit formula of the leading enterprise and the following enterprise:

$$\pi_1^* = \frac{(a-c-me_2+2me_1)^2}{8} - \frac{ye_1^2}{2} \quad (6)$$

$$\pi_2^* = \frac{(a-c+3me_2-2me_1)^2}{16} - \frac{ye_2^2}{2} \quad (7)$$

In the second stage, the leading enterprise and the follower enterprise separately selects the carbon emission reduction per unit of product to maximize their own profits. Set FOC  $\left\{ \begin{array}{l} \frac{\partial \pi_1^*}{\partial e_1} = 0 \\ \frac{\partial \pi_2^*}{\partial e_2} = 0 \end{array} \right\}$  to get the equilibrium carbon reductions for leading and following businesses:

$$e_1^n = \frac{(15m^3-4my)A}{B} \quad (8)$$

$$e_2^n = \frac{(6m^3-3my)A}{B} \quad (9)$$

Where:

$$A = a - c$$

$$B = 17ym^2 - 8y^2 - 6m^4$$

indicating that the equilibrium carbon emission reduction per unit product of the enterprise is related to consumers' low carbon preference and the enterprise's emission reduction investment efficiency. Substitute equations (8) and (9) into equations (4) and (5) to obtain the optimal output of the leading enterprise and the following enterprise as:

$$q_1^n = \frac{(15ym^2-8y^2-9m^4)A}{2B} \quad (10)$$

$$q_2^n = \frac{(11ym^2-8y^2+27m^4)A}{4B} \quad (11)$$

Substitute equations (8), (9), (10), and (11) into equations (6) and (7) to obtain the equilibrium profits of the leading enterprise and the following enterprise under competitive conditions:

$$\pi_1^n = \frac{(513y^2m^4-414ym^6-276m^2y^3+64y^4+81m^8)A^2}{8B^2} \quad (12)$$

$$\pi_2^n = \frac{(409y^2m^4+64y^4+729m^8-248m^2y^3-126ym^6)A^2}{16B^2} \quad (13)$$

And the consumer surplus:

$$CS^n = \frac{(2C+D)^2A^2}{32B^2} \quad (14)$$

$$C = 15ym^2 - 8y^2 - 9m^4$$

$$D = 11ym^2 - 8y^2 + 27m^4$$

In the first stage, leaders and followers choose how to participate in the market by comparing equilibrium profits under different scenarios.

### 3.2.2. The optimal carbon emission reduction decision of enterprises under the cooperation model

In this scenario, the leading firm and the follower firm maintain independent decision-making, but aim at maximizing total profits. The third stage remains the same, while in the second stage, the two companies choose to maximize total profits (下方下方).

$$\max(\pi_1^* + \pi_2^*) = \frac{(a-c-me_2+2me_1)^2}{8} - \frac{ye_1^2}{2} + \frac{(a-c+3me_2-2me_1)^2}{16} - \frac{ye_2^2}{2} \quad (15)$$

Through the same solution process as under the competition case, it derives into:

$$e_1^c = \frac{(4m^3-2ym)A}{E} \quad (16)$$

$$e_2^c = \frac{(4m^3-ym)A}{E} \quad (17)$$

$$q_1^c = \frac{(10ym^2-4y^2)A}{E} \quad (18)$$

$$q_2^c = \frac{(6ym^2-2y^2+4m^4)A}{E} \quad (19)$$

$$\pi_1^c = \frac{2y(29ym^4+4y^3-21m^2y^2-4m^6)A^2}{E^2} \quad (20)$$

$$\pi_2^c = \frac{(80ym^6+8y^4-49m^2y^3+32m^8+48y^2m^4)A^2}{2E^2} \quad (21)$$

Consumer Surplus:

$$CS^c = \frac{(F+G)^2 A^2}{2E^2} \quad (22)$$

Hence:

$$E = 23ym^2 - 8y^2 - 4m^4$$

$$F = 10ym^2 - 4y^2$$

$$G = 6ym^2 - 2y^2 + 4m^4$$

## 4. Result Analysis

This section will focus on the impact of consumers' low-carbon preferences on corporate carbon reduction decisions, focusing on the market conditions under which leaders and followers will establish cooperative relationships, and the impact of consumers' low-carbon preferences on corporate carbon reduction under these conditions. What is the impact on volume and profit, and further, pay attention to the impact of consumers' low carbon preference on the environment and society.

### 4.1. How companies participate in the market

To explore the way enterprises participate in the market, it is necessary to compare the establishment conditions of the leaders and followers' emission reduction cooperation and competition, that is, the equilibrium profit difference of enterprises under different scenarios. Assuming that  $\Delta\pi_i = \pi_i^c - \pi_i^n (i = 1,2)$ , when  $\Delta\pi_i \geq 0$ , it means that the company has the willingness to cooperate; when  $\Delta\pi_i < 0$ , it means that the company will not establish a cooperative relationship. If and only when  $\Delta\pi_1 \geq 0, \Delta\pi_2 \geq 0$ , the cooperation scenario of enterprises is established, and under other market conditions, enterprises are in competition mode. When the value of  $m$  is too large, the spontaneous adjustment of the market makes all levels of enterprises converge, so to ensure that the value is meaningful, that is when  $e_i^k, q_i^k, \pi_i^k > 0$ , it takes  $0 < m < 4$ . The change trend of corporate profit margin with  $m$  is shown in Figure 1, and proposition 1 is put forward.

Proposition 1: Only when consumers' low carbon preference is at a relatively high level ( $m_1 < m < m_2, 3 < m_1 < 3.5, 3 < m_2 < 3.5$ ), the leading enterprise and the follower enterprise will establish a

cooperative relationship, while under the low carbon preference level of other consumers, the leading enterprise and the follower enterprise are in a competitive relationship.

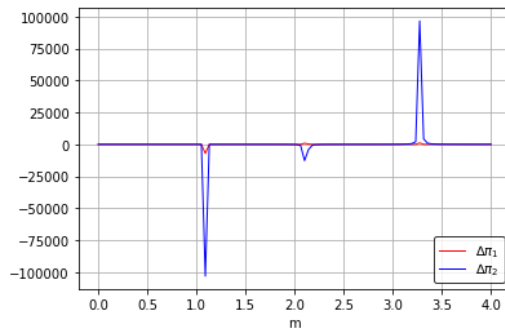


Figure 1: Variation trend of  $\Delta\pi_i$  to  $m$

At present, scholars' research mostly focuses on static competition. This paper studies sequential output competition and finds that when consumers have a significant preference for low-carbon products, enterprises will cooperate in carbon emission reduction, and cooperation can not only share technology and experience between enterprises, but also can effectively reduce the cost of enterprises. At the same time, companies always have the only choice for consumers with different low-carbon preference levels. Therefore, enterprises can choose the appropriate form of output competition according to consumers' low carbon preference level to obtain more market opportunities. When consumers' low carbon awareness is not obvious, companies are reluctant to participate in active emission reduction actions. At this time, appropriate government regulations can promote companies to produce emission reduction behaviors. With the strengthening of consumers' low carbon awareness, the government can strengthen consumer guidance It can further promote the remaining enterprises to join the ranks of active emission reduction and reduce the financial support pressure of the government.

#### 4.2. The impact of consumers' low carbon preference on corporate carbon emission reduction decisions

The carbon emission reduction of the main decision-making unit of the enterprise's carbon emission reduction decision can be compared with the carbon emission reduction per unit product of the leading enterprise and the follower enterprise in the same scenario and different scenarios, as well as the carbon emission reduction per unit product between enterprises. In order to bring different dimensions of reference for enterprise decision-making. The change trend of carbon emission reduction per unit product of enterprise  $i$  with  $m$  is shown in Figure 2, and proposition 2 is proposed.

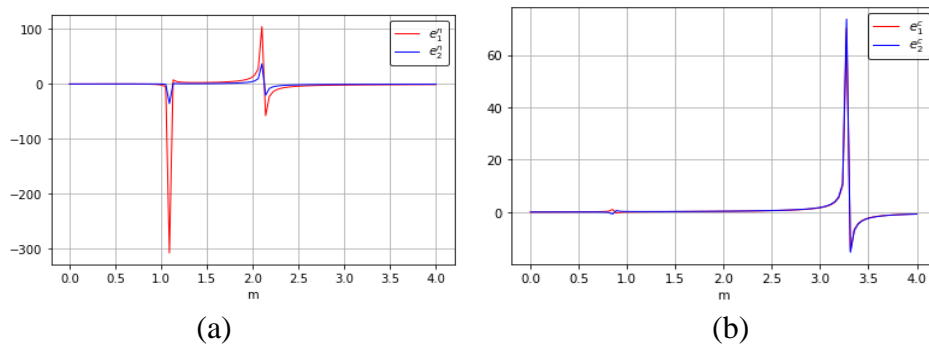


Figure 2: The variation trend of carbon emission reduction per unit product of different enterprises with  $m$  under the same scenario



Proposition 2: Assuming  $e_i^k > 0, (i = 1, 2; k = c, n)$ :

- 1) Under the competitive scenario, the carbon emission reduction per unit product of the leading enterprise is higher than that of the following enterprise;
- 2) Under the cooperation scenario, the carbon emission reduction per unit product of the leading enterprise tends to be at the same level as the carbon emission reduction per unit product of the follower enterprise.

Proposition 2 shows that under the very low or high level of consumers' low carbon preference, there is no promotion effect on the carbon emission reduction of enterprises. Whether it is competition or cooperation, leading companies are in a better position to reduce carbon emissions, while for follower companies, seeking cooperation will lead to higher levels of carbon emissions reductions. This is mainly caused by two reasons: first, when consumers' low carbon preference is extremely low, the cost of companies actively participating in emission reduction activities is relatively high. way to avoid their own costs. When consumers' low-carbon preference is extremely high, companies see the cost dividends and market competitiveness brought by consumers' low-carbon preference, which can not only reduce their own emission reductions, but also gain greater market share and profits. Actively participate in emission reduction actions. Second, corporate activities have a "free-rider effect". For leading companies, as the first entrants in the market, leading companies have implicitly assumed greater carbon responsibilities and costs. While reducing their own carbon emission reductions, they also reduce the other party's emission reduction costs to a certain extent. However, due to the lack of capital scale of the follower companies, in the case of low carbon preference of consumers, the emission reduction ability is weak, and at the same time, competition reduces the concentration of emission reduction of enterprises. Therefore, seeking a cooperation model can bring a closed loop of the market ecology.

According to Figure 2, consumers' low-carbon preference in the cooperation scenario is greater than that in the competition scenario, and the carbon emission reduction per unit product of the enterprise increases with the increase of consumers' low-carbon preference. As consumers' low-carbon preference becomes more and more obvious, enterprises should shift from competitive relationship to cooperative relationship. Cooperation can positively promote the spillover effect of emission reduction among enterprises, so that enterprises can obtain greater benefits.

In addition to the emission reduction level under the same scenario, the variation trend of the emission reduction level with  $m$  under different scenarios of the same enterprise is shown in Figure 3, from which Inference 1 is proposed.

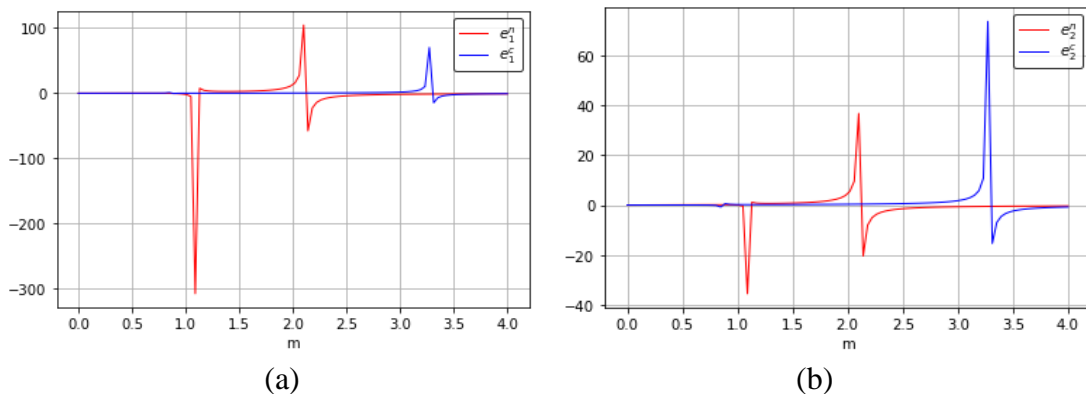


Figure 3: Variation trend of carbon emission reduction per unit product of the same enterprise with  $m$  under different scenarios

Inference 1: Assuming  $e_i^k > 0, (i = 1, 2; k = c, n)$ :

- 1) When consumers' low carbon preference is low ( $1 < m < 2.5$ ), the carbon emission reduction per unit product of the enterprise under the competition scenario is higher than that under the cooperation

scenario;

2) When consumers' low carbon preference is high ( $3 < m < 3.5$ ), the carbon emission reduction per unit product of the enterprise under the cooperation scenario is higher than that under the competition scenario.

### 4.3. The impact of different market conditions on the industry

The above mainly focuses on the impact of different market conditions on a single enterprise. In order to further extend the social impact of different market conditions, this section mainly focuses on the impact of enterprise competition and enterprise cooperation on industry output and industry carbon emission reduction. Assuming  $Q^k = q_1^k + q_2^k, S^k = e_1^k * q_1^k + e_2^k * q_2^k, (k = c, n)$ , the change trend of  $Q^k, S^k$  according to  $m$  is shown in Figure 4, from which proposition 3 is proposed.

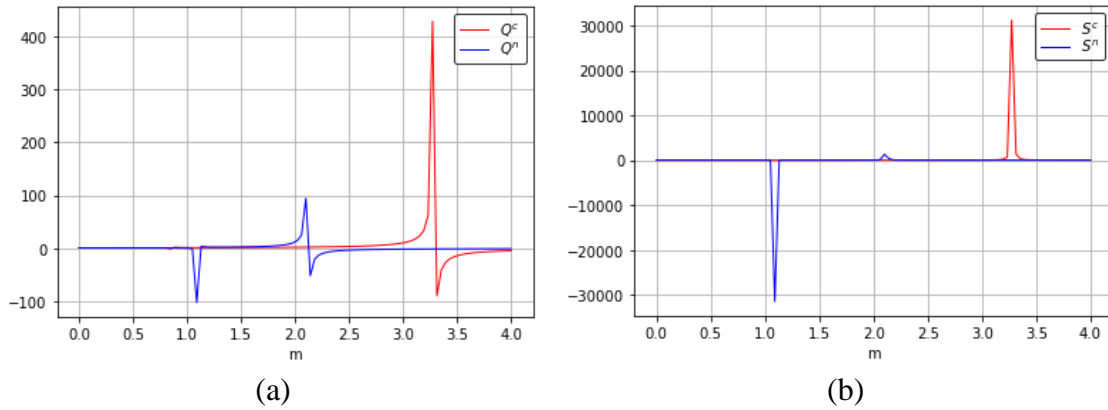


Figure 4:  $Q^k, S^k (k = c, n)$  changing trend according to  $m$

Proposition 3: Assuming  $Q^k > 0, S^k > 0 (i = 1, 2; k = c, n)$ :

1) When consumers' low carbon preference level is low ( $1.5 < m < 2.5$ ), the industry output under the competition scenario is greater than that under the cooperation scenario; when consumers' low carbon preference level is high ( $2.5 < m < 3.5$ ), the industry output under the cooperation scenario is greater than that under the competition scenario;

2) When consumers' low carbon preference level is high ( $3 < m < 3.5$ ), the industry carbon emission reduction under the cooperation scenario is greater than that under the competition scenario;

Proposition 3 shows that when consumers' low carbon preference level is low ( $1.5 < m < 2.5$ ), corporate competition improves the overall emission reduction level of the industry, and when consumers' low carbon preference level is relatively high ( $3 < m < 3.5$ ), business cooperation has improved the overall level of the industry. This conclusion once again verifies that when consumers have a high level of low-carbon preference, enterprise cooperation can not only balance the carbon emission reduction level of a single enterprise, but also improve the overall carbon emission reduction level of the industry. Although it avoids fierce corporate competition to a certain extent, it also means charging consumers higher fees, which often reduces consumers and damages social welfare. When consumers' low carbon preference level is low, the multiplication of competition effect between enterprises will increase the gap between enterprises, and the increase of the production cost of the other company will indirectly improve the competitiveness of their own enterprises. In addition, leading enterprises have relatively few resource constraints, and with the support of external forces such as government regulations, they are more able to actively participate in the ranks of carbon emission reduction.

## 5. Case Analysis

The preceding article assumes that the leading firm and the follower firm have symmetric market sizes and marginal production costs, but in reality, there are often asymmetric market sizes and marginal production costs between firms. Therefore, in order to further highlight the uneven market power of leading companies and following companies, this section assigns values to different market sizes and marginal production costs of companies, and analyzes the impact of consumers' low-carbon preferences on companies, industries and consumers through an example.

Setting fixed values as  $a_1 = 100, a_2 = 70, c_1 = 10, c_2 = 20$ , the trend of industry carbon emission reduction( $S$ ), total output( $Q$ ), total profit( $\pi$ ) and consumer surplus( $CS$ ) according to  $m$  is shown in Figure 5. Here it's assumed that  $0 < m < 0.5$  because  $e_i^k > 0 (i = 1, 2; k = c, n), m > 0$ .

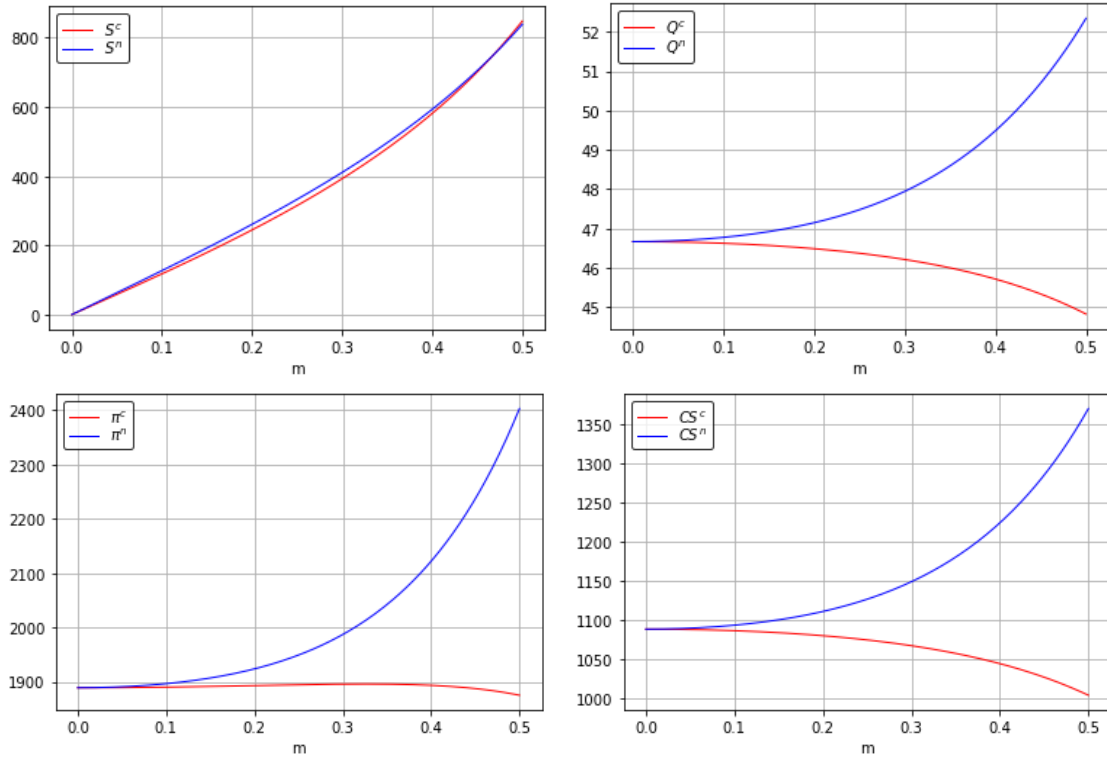


Figure 5:  $S^k, Q^k, \pi^k, CS^k (k = c, n)$ 's trend according to  $m$

It can be seen from Figure 5 that when consumers' low carbon preference level is low, enterprises are in a state of competition. With the enhancement of consumers' low carbon preference level, enterprise competition can increase the total output, total profit and consumer surplus of the industry, and the carbon emission reduction of the industry is slightly higher in the state of enterprise competition than in the state of enterprise cooperation. This may be because when consumers have a low level of low-carbon preference, companies will not give too much to the environment, and their investment in emission reduction is still low, resulting in the overall carbon emission reduction of the industry under the state of enterprise cooperation and competition. There is no significant change, and with the enhancement of consumers' low-carbon preference, the overall carbon emission reduction of the industry will increase with it. When consumers' low carbon preference level is low, the competition between large and medium-sized enterprises of the same category is still in a relatively fierce state. The competition promotes the increase of industry output, brings more profits, and is more beneficial to consumers. Since market regulation may be ineffective, the government can intervene when consumers' low carbon preference level is low, and further enhance consumers' low carbon preference level through publicity and various incentive measures, and increase the

willingness of enterprises to cooperate. At the same time, build bridges for large and medium-sized enterprises, strengthen guidance, and encourage large enterprises and small and medium-sized enterprises to strengthen cooperation in emission reduction.

## 6. Conclusion and Suggestion

Under the strong constraints of the dual-carbon background, it has become an inevitable trend for enterprises to join the ranks of carbon emission reduction. As consumers' low-carbon preference continues to grow, companies have begun to take the initiative to join carbon reduction actions. In the face of the unbalanced market power under the emission reduction action, companies often need to consider how to join the emission reduction action. Large enterprises that enter the emission reduction market first have a first-in advantage and have certain advantages in seeking competition and cooperation, while small and medium-sized enterprises need to rely on the power of the market, the government or leading enterprises to ensure that they are not eliminated by the market due to their small scale of funds.

Therefore, this paper constructs a three-stage dynamic game model to study the active emission reduction decisions of leading and following enterprises. On the one hand, it pays attention to the willingness of enterprises to actively participate in emission reduction actions under different consumers' low-carbon preferences; on the other hand, considers the sequential output competition of enterprises and pays attention to the influence of different market forces, which makes up for the neglect of the market in the existing literature. The phenomenon of uneven power and the lack of exploration of consumers' low carbon preferences. The study found: First, consumers' low carbon preference level has a significant impact on whether companies join carbon emission reduction actions; when consumers' low carbon preference level is too low or too high, companies often choose to compete in emission reduction, while when consumers are low carbon. When the level of carbon preference is at a significant level, companies will choose to cooperate in emission reduction. Second, the carbon emission reduction per unit product of the leading enterprise is higher than the carbon emission reduction per unit product of the follower enterprise in the emission reduction competition, and in the emission reduction cooperation, the carbon emission reduction per unit product of the leading enterprise is higher than that of the follower enterprise. Product carbon emission reductions tend to be at the same level. Third, emission reduction cooperation can increase the industrial output of enterprises and the carbon emission reduction of the industry, which is beneficial to the industry as a whole. Based on the research results, the following recommendations are made:

First of all, there is an optimal interval for consumers' low carbon preference level, which can prompt enterprises to achieve emission reduction cooperation without government intervention. Too low or too high consumers' low carbon preference level is not conducive to enterprises achieving emission reduction. Cooperation. Emission reduction cooperation can not only enable leading enterprises to maintain a high emission reduction level, but also improve the emission reduction effect of small and medium-sized enterprises in the industry, which greatly promotes the overall carbon emission reduction level of the industry, and is a good help for achieving the dual carbon goal. With the increase of consumers' low carbon preference, in the long run, enterprises will invest more carbon emission reduction efforts, and enterprises will seek cooperation to reduce emission reduction costs and maximize profits. The lack of incentives for companies to actively reduce carbon emissions often occurs when consumers' low carbon preference level is too low. Therefore, in addition to subsidy incentives, the government can take appropriate measures to stimulate consumers' low carbon preference, thereby enhancing corporate emission reductions. Willingness to cooperate. On the one hand, strengthen the publicity of low-carbon consumption concepts or force consumers to conduct low-carbon behaviors within a period of time, such as volunteers urging garbage sorting, so that

consumers can form clear and stable low-carbon preferences; on the other hand, set relevant low-carbon behaviors. Low-carbon standards or providing diversified financing channels to match the green awareness of enterprises and consumers, lower the threshold for enterprises to guide consumers' low-carbon preferences, and thus promote a win-win situation for the government, enterprises and consumers. When consumers have a high level of low-carbon preference, vicious competition between companies may lead to increased operating costs of each other, but there is no substantial improvement in the company's own carbon emission reduction level. The government should formulate relevant laws and regulations to increase the company's Competitive costs or raising the competitive threshold of enterprises.

Secondly, as the main force of carbon emission reduction, enterprises can choose how to participate in emission reduction actions according to their actual situation. Enterprises of different sizes are under different pressures in emission reduction actions. Enterprises that become the first entrants in the emission reduction market have a first-mover advantage but also increase their emission reduction costs. When consumers have a low level of low-carbon preference, companies should put more effort into product or brand concepts to enhance consumers' awareness of low-carbon consumption. With the continuous improvement of the quality of consumer groups and the continuous enhancement of consumers' low carbon awareness, enterprises should actively seek emission reduction cooperation with other enterprises or the entire supply chain, and based on the government's incentive policies, amplify the effect of emission reduction efforts. However, enterprises should not form unfair competition because they seize the market scale, which will not only increase operating costs, but also run counter to the goal of carbon emission reduction.

There are still some shortcomings in this paper. These conclusions are based on the duopoly market. Extending the analysis to the multilateral market will exacerbate the free-rider problem of enterprises, and there will also be the cross-influence problem of multiple competition and cooperation. Therefore, it is necessary to further consider the emission reduction competition and emission reduction cooperation of multiple enterprises, which may bring more valuable conclusions and suggestions for enterprise management and government decision-making.

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