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INFORMATION DECISION MAKING AND COORDINATION BETWEEN BUSINESS LEADERS AND FOLLOWERS BASED ON LOW-CARBON BEHAVIOR

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Abstract

Based on the consideration of low-carbon policies, the article constructs a low-carbon behavior model of investment cooperation consisting of leaders and followers. The article analyzes the game models under full cooperation, full non-cooperation and low-carbon behavior cost-sharing, and the results show that: the low-carbon behavior cost-sharing coefficient affects the level of low-carbon behavior in the three games; the benefits under the full non-cooperation cooperation and cost-sharing model are affected by the low-carbon behavior cost-sharing coefficient; the coordination of investments cannot be achieved under the full non-cooperation and low-carbon behavior cost-sharing decisions; the cost-sharing of low-carbon behavior. The market price in the model is optimized for the Nash negotiation game to achieve the overall investment optimum and the Pareto optimum for both parties; the article concludes with a numerical simulation analysis of the sensitivity of the parameters.

Key words: decision making, followers, leaders, low-carbon

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1. Introduction

In recent years, the emission of greenhouse gases such as carbon dioxide caused by human activities has increased dramatically, and the resulting global warming poses a serious threat to global ecosystems and humans (Du et al., 2018). As an important subject of human activities, enterprises are facing challenges from various aspects in taking responsibility for climate change, and more and more investors hope to allocate more funds to low-carbon and climate-related green investments. Doda et al. (2016) quantified the impact of corporate carbon management practices on corporate GHG emissions. Zhao et al. (2017) proposed a new method to assign carbon emissions to different industries in China, based on input-output analysis and entropy weights.

Green investment, as a new type of sustainable investment, is in line with the current concept of green development, upholding the principles of environmental friendliness and resource conservation, reducing environmental externalities in traditional investment and taking into account corporate social responsibility, with the aim of achieving sustainable development between the economy, society and the environment, so as to build a green and low-carbon community of human destiny. In the first half of the 20th century, the Coalition for Environmentally Responsible Economies (CERES) was formed to promote sustainable development between the economy, society and the environment, and to build a green and low-carbon community of human destiny. Economics (CERES) and SIF have joined forces to call on investors to join in the development of the Valdez Principles. In this principle, the concept of green investment is elaborated for the first time, and

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the concept of green investment is used to call on people to unite and resist investment methods that only care about immediate profits and damage the ecological environment, and to encourage people to pursue capital gains, but also to take individual social responsibility, not at the expense of the environment in the process of making profits. In Western society, green investment, as an important representative of "socially responsible investment", is often considered to be an investment based on the three principles of environmental, social and monetary returns. Because it takes into account the social, environmental and economic aspects of the three at the same time, it is also known as a "triple surplus" investment. As Gong et al. (2019a) and Zhang et al. (2019) demonstrated that enterprise green investment refers to the concept of sustainable development under the guidance of technological innovation, institutional innovation, industrial upgrading, new energy development and utilization of innovative investment, to reduce resource waste and environmental pollution, in order to achieve the win-win green normalized management mode (Gong et al., 2019b).

Research on green investment has progressed rapidly in recent years. Earlier studies mainly discussed green investment from the perspective of environmental finance, emphasizing the principles of environmental protection. The focus was mainly on how to apply financial techniques to the assessment and pricing of environmental externalities and shared resources (e.g., biodiversity) to promote environmental protection and achieve sustainable economic development through the integration of environmental and capital markets (Allen and Yago, 2011). Green investments should be those needed to reduce greenhouse gas and air pollutant emissions without significantly reducing the production and consumption of non-energy products (Eyraud et al., 2013). Subsequent studies have interpreted green investment more from the perspective of socially responsible investment, emphasizing that participation in environmental management is the social responsibility of enterprises and a requirement for avoiding environmental risks and achieving their own sustainable development. Enterprises should not only consider economic performance when investing, but also measure the fulfillment of social responsibility from aspects such as environmental protection (Lesser et al., 2014). Josef Zechner's research and analysis of the paths and effect sizes of green investments in influencing corporate behavior found that increasing green investments will increase a company's overall cost of doing business, but it is necessary for companies to build a good corporate image and ultimately gain greater economic benefits by enhancing green investments (Robert et al., 2001). As Starr (2016) demonstrated that when making an investment, a company should not only consider the economic benefits, but also its social responsibility, environmental protection and public interest.

As Maurizio (2018) demonstrated that companies that introduce a social, environmental and governance investment philosophy have a good reputation and, in the long run, do not aim at short-term opportunistic gains, but rather at more sustainable economic benefits.

In the green investment process, on the one hand, the cap-and-trade policy introduced by the government to induce enterprises to save energy and reduce emissions can affect their investment decisions. On the other hand, low-carbon behavioral investment by enterprises will also make the traditional investment decision more complicated (Ma et al., 2020; Wan et al., 2019).

The enterprise is based on the interest to participate in market competition, only stand in the common interests of leaders and followers of the perspective of the study of enterprise investment decision-making behavior, in order to maximize the benefits through the realization. Due to the investment process, driven by interests, leaders generally have a strategic consumer behavior, that is, to conceal the low-carbon behavior of inputs and outputs, through information disclosure means to pursue profit maximization; at the same time, this behavior, followers will also know, but do not understand the specific content.

Therefore, it is of great theoretical and practical value to study the decision-making and coordination issues of considering low-carbon behavior investment, taking into account the investment characteristics of strategic consumer behavior. In this chapter, we introduce low-carbon behaviors and take the investment team composed of "one leader-multiple followers" as the object of study based on information disclosure and investment price consideration, model the expected return of the members, and obtain the optimal decision combination of leader and followers through the methods of game theory and mechanism design, and then further analyze the model. The key parameters of the optimal portfolio and the expected utility of the members after the change of the parameters, to explore the most suitable parameter settings for the members to make decisions.

2. Material and methods

This paper establishes low carbon behavior production conditions for leaders and followers of investment products, where the leader makes low carbon behavior investments to reduce the initial disclosure of the investment product, the market has low carbon behavior controls on the investment product, the leader makes decisions about the market price of the investment product and the amount of income reduction, and the followers determine the investment price of the investment product on this basis. Based on the need for this research, this paper makes the following assumptions:

Hypothesis 1: The unit of disclosure when the leader is not investing in low-carbon behavior is e_0 and followers' trust in the leader is t;

Hypothesis 2: The benefits and costs of a leader's investment product are w and c, respectively;

Hypothesis 3: The investment demand function of the market is $Q = a - bp(a, b > 0)$, where a is the underlying market demand size, b is the price sensitivity factor of market demand, where p is the follower's decision variable and satisfies $p > w > te_0$;

Hypothesis 4: The reduction in income per unit of investment product after a leader makes an investment in low-carbon behavior is Δ. Low carbon behavioral costs met $c(\Delta) = \theta\Delta^2, \theta > 0$, where θ is the leader's cost factor for low-carbon behavior;

Hypothesis 5: Under a green policy, if a leader engages in low-carbon behavior the benefits are profitable, $(a-bc)-bte_0>0$ and $4\theta > bt^2$;

From the above assumptions we can obtain the leader's earnings as (Eq. 1):

$$\pi_m = [w - c - t(e_0 - \Delta)](a - bp) - \theta\Delta^2 \quad (1)$$

The gain function for followers (Eq. 2):

$$\pi_r = (p - w)(a - bp) \quad (2)$$

The overall investment return (Eq. 3):

$$\pi_{sc} = [p - c - t(e_0 - \Delta)](a - bp) - \theta\Delta^2 \quad (3)$$

2.1. Fully cooperative decision-making model

The fully cooperative decision-making model of investment integration in which the leader and the chaser are an integrated system that aims to jointly determine the investment price of investment products p and the amount of income reduction Δin a centralized manner with the goal of maximizing the return of the entire investment system. The overall investment return function for the fully cooperative decision model is in (Eq. 4):

$$\pi^{sc} = [p - c - t(e_0 - \Delta)](a - bp) - \theta\Delta^2 \quad (4)$$

Proposition 1: The existence of an optimal amount of revenue reduction $\Delta$and an optimal follower price p in a fully cooperative decision model its optimal decision is (Eq. 5):

$$\Delta^{sc} = \frac{(a - bc - bte_0)t}{4\theta - bt^2}, \quad p^{sc} = \frac{2\theta(a + bc + bte_0) - abt^2}{4\theta b - b^2t^2} \quad (5)$$

Proof: Eq. (4) shows that the Heiser matrix of π^{sc} with respect to investment price p and income reduction Δ is: $H = (\partial^2\pi_{sc}/\partial\Delta^2)*(\partial^2\pi_{sc}/\partial p^2) - (\partial^2\pi_{sc}/\partial p\partial\Delta)*(\partial^2\pi_{sc}/\partial p^2) = 4b\theta - b^2t^2$ according to $\partial^2\pi_{sc}/\partial\Delta^2 = -2\theta$ and $|H| = 4b\theta - 4b^2t^2$, when available as $4b\theta - 4b^2t^2 > 0$, π^{sc} isa joint concave function about the price of investment p and the amount of income reduction Δ, so there is an optimal solution. Find the first-order derivative of equation (4) with respect to the investment price p and income reduction $\Delta$and make the first-order derivative zero, which yields $\partial\pi_{sc}/\partial p = a - 2bp + bc + bt(e_0 - \Delta) = 0$, $\partial\pi_{sc}/\partial\Delta = t(a - bp) - 2\theta\Delta = 0$

The investment prices p and income reductions Δavailable in the full cooperative decision-making model in the vertical are Eqs. (6-7):

$$p^{sc} = \frac{2\theta(a + bc + bte_0) - abt^2}{4\theta b - b^2t^2} \quad (6)$$

$$\Delta^{sc} = \frac{(a - bc - bte_0)t}{4\theta - bt^2} \quad (7)$$

Bringing Eqs. (6-7) into the demand function and the investment return function, the total demand for investment and the total return on investment in the fully cooperative decision model are (Eq. 8):

$$Q^{sc} = \frac{2\theta(a - bc - bte_0)}{4\theta - bt^2}, \quad \pi^{sc} = \frac{\theta(a - bc - bte_0)^2}{4\theta b - b^2t^2} \quad (8)$$

Characteristic 1: The total benefits π_{sc} of leaders in a fully cooperative decision model are negatively correlated with the cost factor θ of low-carbon behavior; the optimal investment price p^{sc} of followers is positively correlated with θ; and income reductions are all negatively correlated with θ.

Proof: if π_{sc} is a function about θ, then the first-order derivative of π_{sc} is obtained as $\partial\pi_{sc}/\partial\theta = -b^2t^2(a - bc - bte_0)^2/(4\theta b - b^2t^2)^2$. Because $4\theta b - b^2t^2 > 0$, by the same token $\partial\Delta^{sc}/\partial\theta = -4(a - bc - bte_0)t/(4\theta - bt^2)^2 < 0$; $\partial p^{SC}/\partial\theta = 2b^2t^2(a - bc - bte_0)/(4\theta b - b^2t^2)^2 > 0$.

Characteristic 1 show that the total return on investment in a fully cooperative decision model is negatively correlated with the cost of low-carbon coefficient, so that for the entire membership of the investment, increasing the level of low-carbon technology and reducing the cost of low-carbon will benefit all parties.

2.2. Completely uncooperative decision-making model

The leader is in the dominant position and the followers are in the subordinate position in the non-cooperative decision-making model. The leader aims at maximizing his or her own returns by determining the market price of the investment product w and the amount of income reduction Δ according to the low-carbon behavior cost and green rate, and the followers determine the investment price of the investment p

according to the market information and the market price given by the leader, and the return functions of the leader and the followers are as follows Eqs. (9-10):

$$\pi_m = [w - c - t(e_0 - \Delta)](a - bp) - \theta\Delta^2 \quad (9)$$

$$\pi_r = (p - w)(a - bp) \quad (10)$$

Proposition 2: There is an optimal amount of revenue reduction Δ and an optimal follower price p and an optimal market price w in a completely uncooperative decision model, where the optimal decision is (Eq. 11):

$$\Delta^1 = \frac{(a-bc-bte_0)t}{8\theta - bt^2}, p^1 = \frac{2\theta(3a+bc+bte_0)-abt^2}{8\theta b - b^2t^2},$$
$$w^1 = \frac{4\theta(a+bc+bte_0)-abt^2}{8\theta b - b^2t^2} \quad (11)$$

Proof: by the second-order derivative $\partial^2\pi_r / \partial p^2 = -2b < 0$ of Eq. (10) about p, so the followers' return function is a strictly concave function about the optimal investment price, so there exists an optimal investment price p that maximizes the followers' return. Find the first-order function of π_r about p and make it zero to obtain $p = (a + bw)/2b$ and substitute it into (9), where the leader's gain function is (Eq. 12):

$$\pi_m = [w - c - t(e_0 - \Delta)](a - bw)/2 - \theta\Delta^2 \quad (12)$$

Find π_m obtain the second-order partial derivative of the market price w and the reduction in income Δ of the investment product, $\partial^2\pi_m / \partial w^2 = -b$, $\partial^2\pi_m / \partial\Delta^2 = -2\theta$, $\partial^2\pi_m / \partial w\partial\Delta = \partial^2\pi_m / \partial\Delta\partial w = -bt/2$, the Heather matrix in a completely non-cooperative decision-making model is $|H| = 2\theta b - b^2t^2/4 > 0$,When $2\theta b - b^2t^2/4 > 0$, it is known that π_m is a strictly concave function about the market price w and the amount of income reduction Δ, so there is an optimal solution. Finding the first-order derivative of π_m about market prices w and income reductions Δ and making it equal to zero, obtain (Eq. 13):

$$\partial\pi_m / \partial w = a - 2bw + bc + bt(e_0 - \Delta) = 0,$$
$$\partial\pi_m / \partial\Delta = t(a - bw) - 4\theta\Delta = 0 \quad (13)$$

The optimal market price w and income reduction Δ and the optimal investment price p for the perfect non-cooperative decision model are obtained in conjunction with $p = (a + bw)/2b$, respectively (Eq. 14):

$$w^1 = \frac{4\theta(a+bc+bte_0)-abt^2}{8\theta b - b^2t^2}, \ \Delta^1 = \frac{(a-bc-bte_0)t}{8\theta - bt^2},$$
$$p^1 = \frac{2\theta(3a+bc+bte_0)-abt^2}{8\theta b - b^2t^2} \quad (14)$$

Substituting equation p^1 into the demand function, combining w^1, p^1, Δ^1 and equations (9) and (10) yields the demand, the leader's gain, the follower's gain, and the return on investment for the completely non-cooperative decision model as (Eq. 15):

$$Q^1 = \frac{2\theta(a-bc-bte_0)}{8\theta - bt^2}, \ \pi_m^1 = \frac{\theta(a-bc-bte_0)^2}{b(8\theta - bt^2)},$$
$$\pi_r^1 = \frac{4\theta^2(a-bc-bte_0)^2}{b(8\theta - bt^2)^2}, \pi_{sc}^1 = \frac{\theta(12\theta - bt^2)(a-bc-bte_0)^2}{b(8\theta - bt^2)^2} \quad (15)$$

Characteristic 2: The benefits to leaders and followers in a completely non-cooperative decision-making model are π_m^1 negatively related to θ and π_r^1 negatively related to the cost factor θ of low-carbon behavior; Follower's optimal investment price p^{sc} is negatively correlated with θ and the amount of income reduction is negatively correlated with θ.

Proof: if π_m^1 is a function about θ, then the first-order derivative of π_m^1 is obtained $\partial\pi_m^1 / \partial\theta = -t^2(a-bc-bte_0)^2 / (8\theta - bt^2)^2$, because $8\theta - bt^2 > 0$, by the same token $\partial\pi_r^1 / \partial\theta = -8\theta bt^2(a-bc-bte_0)^2 / (8\theta - bt^2) < 0$; $\partial p^1 / \partial\theta = 2t^2(a-bc-bte_0)/(8\theta - bt^2)^2 > 0$

Characteristic 2 illustrates that the price of investment in the completely uncooperative decision model is positively related to the low carbon behavior cost factor, indicating that when the low carbon behavior cost factor is too high, followers increase the price of investment but then the leader and followers' benefits decrease, high low carbon behavior leads to a decrease in benefits for both followers and leaders, so both leaders and followers are willing to invest in low carbon behavior techniques to reduce the low carbon behavior cost factor.

Characteristic 3: Comparing the fully cooperative and fully non-cooperative models yields income reductions, investment volumes, investment prices, and the magnitude of the return on investment for the two-decision model $\Delta^1 < \Delta^{sc}$, $Q^1 < Q^{sc}$, $\pi_{sc} > \pi_{sc}^1$, $p^1 > p^{sc}$.

Proof: from the calculations of the fully cooperative and fully non-cooperative models, it is easy to know that $\Delta^{sc} - \Delta^1 = 4\theta t(a-bc-bte_0)/(4\theta - bt^2)(8\theta - bt^2)$ by $(a-bc-bte_0) > 0, 4\theta - bt^2 > 0, 8\theta - bt^2 > 0$ known $\Delta^1 < \Delta^{sc}$;

$Q^{sc} - Q^1 = 4\theta(a-bc-bte_0)/(4\theta-bt^2)(8\theta-bt^2) \Rightarrow Q^1 < Q^{sc}$

$\pi_{sc}^1/\pi_{sc} = (\pi_m^1+\pi_r^1)/\pi_{sc} =$

$[(8\theta-bt^2)^2-16\theta^2]/(8\theta-bt^2)^2 < 1 \Rightarrow \pi_{sc} > \pi_{sc}^1$;

$p^{sc} - p^1 = -8\theta b(a-bc-bte_0) < 0$.

Characteristic 3 shows that the income reduction and investment price per unit of investment product under the fully cooperative decision model is greater than the investment price per unit of investment product under the fully non-cooperative decision model; i.e. $\Delta^1 > \Delta^{sc}$ and $p^1 > p^{sc}$; the demand under the fully non-cooperative decision model is less than the demand under the fully cooperative decision model, i.e. $Q^1 < Q^{sc}$; and the return on investment under full cooperation is greater than the return on investment under incomplete cooperation, i.e. $\pi_{sc} > \pi_{sc}^1$, when there is a double marginalization effect on investment.

2.3. Low carbon behavioral cost sharing decision model

In the low-carbon behavior cost-sharing decision model, followers share the leader's low-carbon behavior costs, where the leader is performing low-carbon behavior is only $1-\lambda$ proportional costs, and followers bear the proportion of low-carbon behavior costs that are λ and satisfy $0<\lambda<1$. The benefit functions for the leader and followers are (Eqs.16 and 17):

$$\pi_m = [w-c-t(e_0-\Delta)](a-bp) - \theta(1-\lambda)\Delta^2 \tag{16}$$

$$\pi_r = [p-w](a-bp) - \theta\lambda\Delta^2 \tag{17}$$

Proposition 3: There are optimal revenue reductions Δ and optimal follower prices p and optimal market prices w in the low-carbon behavioral cost-sharing decision model, where the optimal decision is (Eq. 18):

$$\Delta^2 = \frac{(a-bc-bte_0)t}{8\theta(1-\lambda)-bt^2}, p^2 = \frac{2\theta(1-\lambda)(3a+bc+bte_0)-abt^2}{8\theta(1-\lambda)b-b^2t^2},$$

$$w^2 = \frac{4\theta(1-\lambda)(a+bc+bte_0)-abt^2}{8\theta(1-\lambda)b-b^2t^2} \tag{18}$$

Proof: the second-order derivative of $\partial^2\pi_r/\partial p^2 = -2b < 0$ by equation (17) about p, so the follower's return function is a strictly concave function about the optimal investment price, so there is an optimal investment price p that maximizes the follower's return. Finding the first-order function of π_r about p and making it zero yields $p=(a+bw)/2b$ and substituting it into (16), and find the first-order derivatives about w and Δ, respectively, and zero, which can be found $\partial\pi_{sc}/\partial w = a-2bw+bc+bt(e_0-\Delta) = 0$, $\partial\pi_m/\partial\Delta = t(a-bw) - 4\theta(1-\lambda)\Delta = 0$.

The optimal market prices w and income reductions Δ and optimal investment prices p for the perfect non-cooperative decision model are obtained in conjunction with $p=(a+bw)/2b$, respectively (Eq. 19):

$$\Delta^2 = \frac{(a-bc-bte_0)t}{8\theta(1-\lambda)-bt^2}, p^2 = \frac{2\theta(1-\lambda)(3a+bc+bte_0)-abt^2}{8\theta(1-\lambda)b-b^2t^2},$$

$$w^2 = \frac{4\theta(1-\lambda)(a+bc+bte_0)-abt^2}{8\theta(1-\lambda)b-b^2t^2} \tag{19}$$

Substituting p^2 into the demand function, combining w^2, p^2, Δ^2 and equations (9) and (10) yields the demand under the low-carbon behavioral cost-sharing decision, the benefits to the leader, the benefits to the followers, and the benefits to the investment as follows (Eq. 20):

$$Q^2 = \frac{2\theta(1-\lambda)(a-bc-bte_0)}{8\theta(1-\lambda)-bt^2},\ \pi_m^2 = \frac{\theta(1-\lambda)(a-bc-bte_0)^2}{b(8\theta(1-\lambda)-bt^2)},$$

$$\pi_r^2 = \frac{4\theta^2(1-\lambda)^2(a-bc-bte_0)^2}{b[8\theta(1-\lambda)-bt^2]^2},$$

$$\pi_{sc}^2 = \frac{\theta(1-\lambda)[12\theta(1-\lambda)-bt^2](a-bc-bte_0)^2}{b[8\theta(1-\lambda)-bt^2]^2} \tag{20}$$

Characteristic 4: The benefits of leaders and followers in the low-carbon behavior cost-sharing decision model π_m^2 are negatively correlated with θ, π_r^2 is negatively correlated with the low carbon behavioral cost factor θ;Follower's optimal investment price p^2 is negatively correlated with θ and the amount of income reduction are both negatively correlated with θ.

Proof: if π_m^1 is a function about θ, then the first-order derivative of $\partial\pi_m^2/\partial\theta = -t^2(a-bc-bte_0)^2/(8\theta(1-\lambda)-bt^2)^2$ is obtained, because $8\theta(1-\lambda)-bt^2 > 0$, by the same token $\partial\pi_r^2/\partial\theta = -8\theta(1-\lambda)bt^2(a-bc-bte_0)^2/(8\theta(1-\lambda)-bt^2) < 0$; $\partial p^1/\partial\theta = 2t^2(a-bc-bte_0)/(8\theta(1-\lambda)-bt^2)^2 > 0$.

Characteristic 5: Comparing the investment returns under full cooperation and low-carbon behavior cost-sharing shows that the return on investment under the cost-sharing decision model is less than the return on investment under the full cooperation decision model, i.e. $\pi_{sc} > \pi_{sc}^2$, when the low-carbon behavior cost-sharing contract cannot achieve investment coordination.

Proof: From the calculations of the fully cooperative decision model and the cost-sharing decision model, we know that (Eq. 21):

$$\pi_{sc}-\pi_{sc}^2=\pi_{sc}-(\pi_m^2+\pi_r^2)= \\ =\frac{\theta(1-\lambda)^2(16\theta+12bt^2)-16\theta(1-\lambda)bt^2+4\theta bt^2}{(4\theta b-b^2t^2)[8\theta(1-\lambda)-bt^2]^2}*(a-bc-bte_0)^2 \quad (21)$$

Order $A=(1-\lambda)$ and $0<A<1$,while ordering $B=\theta(1-\lambda)^2(16\theta+12bt^2)-16\theta(1-\lambda)bt^2+4\theta bt$,treating B as a quadratic equation of $(1-\lambda)$, it follows that $B=\theta A^2(16\theta+12bt^2)-16\theta Abt^2+4\theta bt$ is the parabola that satisfies about A,from the discriminant $\Delta_A=4bt^2(bt^2-4\theta)<0$ we get that B is disjoint and constant greater than zero with x,thus satisfying $\pi_{sc}-(\pi_m^2+\pi_r^2)$ constant is positive, i.e. the return on investment under the low-carbon behavior cost-sharing decision is less than the total return on investment under the fully cooperative decision, at which point the investment is uncoordinated.

3. Results

3.1. Comparative analysis under three decision models

Summarizing the scenarios under full cooperation, full non-cooperation and cost-sharing decisions, the level of low-carbon behavior and the benefits of the investment for the three game scenarios can be obtained as shown in Table 1.

Characteristic 6: The magnitude of the return on investment π_{sc}^1 under the fully non-cooperative decision model and the return π_{sc}^2 in the low-carbon cost-sharing decision model is uncertain and depends on the value of the cost-sharing ratio λ.

Proof: $\pi_m^1-\pi_m^2=[-\lambda\theta t^2(a-bc-bte_0)^2]/[(8\theta-bt^2)(8\theta(1-\lambda)-bt^2)]<0$, benefits to the completely uncooperative leader are less than the total benefits to the leader under the cost-sharing contract; order $(1-\lambda)=A, 0<A<1$, we have $\pi_r^1-\pi_r^2=\{\theta(a-bc-bte_0)^2[-A^2(b^2t^4-16\theta bt^2)-16\theta Abt^2+b^2t^4]\}/ /[(8\theta-bt^2)^2(8\theta(1-\lambda)-bt^2)^2]$, then let $M=-A^2(b^2t^4-16\theta bt^2)-16\theta Abt^2+b^2t^4$ be the parabola of the image opening upwards, by which the discriminant formula $\Delta_A=2b^2t^4(8\theta-bt^2)>0$, the solution of the quadratic equation $M=0$ exists, and $M_1=0, M_2>0$.The size of $M=\pi_r^1-\pi_r^2$ therefore depends on λ. From the above analysis it follows that $\pi_{sc}^1-\pi_{sc}^2=\pi_m^1-\pi_m^2+\pi_r^1-\pi_r^2$ also depends on the proportion of this assessment λ。

Characteristic 7: (1) when $0<\lambda<1/2$, $\Delta^2>\Delta^{sc}>\Delta^1$, the revenue reduction under the market price contract is smallest and the revenue reduction under the low-carbon behavioral cost-sharing contract is largest; (2) when $\lambda=1/2$, $\Delta^{sc}=\Delta^2>\Delta^1$, the revenue reduction under the low-carbon behavioral cost-sharing contract is the same as the revenue reduction under the low-carbon behavioral cost-sharing contract and the revenue reduction under the market price contract is smallest; (3) when $1/2<\lambda<1$, $\Delta^2<\Delta^{sc}<\Delta^1$, the revenue reduction under the market price contract is largest. Minimal revenue reductions under the low-carbon behavior cost-sharing compact.

Proof: from Table 1, $\Delta^{sc}=(a-bc-bte_0)t/(4\theta-bt^2)$, $\Delta^1=(a-bc-bte_0)t/(8\theta-bt^2)$, $\Delta^2=(a-bc-bte_0)t/[8\theta(1-\lambda)-bt^2]$, the comparison shows that when $0<\lambda<1/2$, $\Delta^2>\Delta^{sc}$, at the same time $\Delta^{sc}<\Delta^1$; the same reasoning shows that when $\lambda=1/2$, $\Delta^{sc}=\Delta^2>\Delta^1$; when $1/2<\lambda<1$, $\Delta^2<\Delta^{sc}<\Delta^1$.

3.2. Coordinated design of investment contracts

From the above analysis, it can be seen that there are double marginalization effects in both the completely uncooperative, and low-carbon behavior cost-sharing decision models, so there is room for optimization in both decision models. In this section, we optimize the low-carbon behavior under the low-carbon behavior cost-sharing model, and the optimization idea of the completely uncooperative decision model is the same as that of the low-carbon behavior cost-sharing model, which will not be repeated in this paper. For the low-carbon behavior cost-sharing decision model, optimize for the market price that the leader gives the followers, when the amount of investment is Q^3, the investment price is p^3 and the amount of income reduction is Δ^3. The leader gives a market price w^3 that is acceptable to the followers, when the revenue function for the leader and the followers is Eqs. (22-23):

$$\pi_m=[w-c-t(e_0-\Delta)](a-bp)-\theta(1-\lambda)\Delta^2 \quad (22)$$

$$\pi_r=(p-w)(a-bp)-\theta\lambda\Delta^2 \quad (23)$$

Proposition 4: When a leader gives followers an investment price to meet $w_{min}<w^3<w_{max}$,The benefits to the leader and followers are no less than the benefits of the low-carbon behavior component. The incremental benefits to the leader and followers relative to the low-carbon behavior cost-sharing decision model are $\Delta\pi_m^3=(w^3-w_{min})Q^3$ and $\Delta\pi_r^3=(w_{max}-w^3)Q^3$, respectively, and $\Delta\pi_{sc}$ satisfies $\Delta\pi_{sc}=(w_{max}-w_{min})Q^3$

Proof: since neither the leader's nor the follower's gain is less than the maximized gain in the low-carbon behavior cost-sharing scenario, $\pi_r^3>\pi_r^1, \pi_m^3>\pi_m^1$ is obtained, i.e. $(p^3-w)Q^3-\theta\lambda\Delta^3>\pi_r^2$,by $[w-c-t(e_0-\Delta^3)]Q^3-\theta(1-\lambda)(\Delta^3)^2>\pi_m^2$ known $w\le(p^3Q^3-\pi_r^2)/Q^3$,and $w\ge[\pi_m^2+\theta(1-\lambda)(\Delta^3)^2+cQ^3-t(e_0-\Delta^3)Q^3]/Q^3$,order $w_{min}=[\pi_m^2+\theta(1-\lambda)(\Delta^3)^2+cQ^3+t(e_0-\Delta^3)Q^3]/Q^3$, $w_{max}=(p^3Q^3-\pi_r^2)/Q^3$, obtain $\Delta\pi=(w_{max}-w_{min})Q^3$

Table 1. Comparison of three game models

Variable	*Full cooperation*	*Totally uncooperative*	*Low carbon behavioral cost sharing*
Δ	$\frac{(a-bc-bte_0)t}{4\theta-bt^2}$	$\frac{(a-bc-bte_0)t}{8\theta-bt^2}$	$\frac{(a-bc-bte_0)t}{8\theta(1-\lambda)-bt^2}$
π_{sc}	$\frac{\theta(a-bc-bte_0)^2}{4\theta b-b^2t^2}$	$\frac{\theta(12\theta-bt^2)(a-bc-bte_0)^2}{b(8\theta-bt^2)^2}$	$\frac{\theta(1-\lambda)[12\theta(1-\lambda)-bt^2](a-bc-bte_0)^2}{b[8\theta(1-\lambda)-bt^2]^2}$

It follows from Proposition 4 that when $w^3 = w_{\min}$ is satisfied, there is no increase in the leader's gain and all of the increase $\Delta\pi_{sc}$ is gained by the followers; conversely, when $w^3 = w_{\max}$ is satisfied, there is no increase in the followers' gain and all of the increase $\Delta\pi_{sc}$ is gained by the leader.

Since the market price is not determined by the leader alone, the determination of the market price w is related to the bargaining power of the leader and the followers, and this section uses the value of w determined by the Nash bargaining that the bargaining power of the followers is $\alpha, 0<\alpha<1$ and the bargaining power of the corresponding leader is $1-\alpha$ From the Nash bargaining model, the problem of finding the optimal w at this point boils down to N: where $N:\underset{w}{Max} = (\pi_r^3-\pi_r^2)^{\alpha}(\pi_m^3-\pi_m^2)^{(1-\alpha)}$, i.e.,(Eq. 24):

$$N:\underset{w}{Max} = [(p^3-w)Q^3-\pi_r^2]^{\alpha}\left\{[w-c-t(e_0-\Delta^3)]Q^3 - -\theta(1-\lambda)(\Delta^3)^2-\pi_m^2\right\}^{(1-\alpha)} \tag{24}$$

Solving for Eq. (24), we can obtain $w=(p^3-\pi_r^2-\alpha\Delta\pi)/Q^3$, thus, the bargaining power of followers affects the leader's market price, and the leader's market price is negatively related to the bargaining power of followers.

Proposition 5: It follows from the Nash bargaining model that there is an optimal market price that satisfies investment coordination w, and w satisfies $w_{\min}<w^3<w_{\max}$, at which point investment prices, demand and income reductions are equal to those obtained when the decision model is fully cooperative.

Proof: find the first-order derivative of equation (24) about w and make the first-order derivative zero, obtain (Eq. 25):

$$\frac{\partial N}{\partial w} = Q^3[(p^3-w)Q^3-\pi_r^2]^{\alpha}\left\{[w-c-t(e_0-\Delta^3)]Q^3-\theta(1-\lambda)(\Delta^3)^2-\pi_m^2\right\}^{-\alpha} * \left\{\frac{-\alpha\{[w-c-t(e_0-\Delta^3)]Q^3-\theta(1-\lambda)(\Delta^3)^2-\pi_m^2\}}{(p^3-w)Q^3-\pi_r^1}+1-\alpha\right\} \tag{25}$$

It results (Eq. 26):

$$w^3 = \frac{p^3-\pi_r^2-\alpha\{[p^3-c-t(e_0-\Delta^3)]Q^3-\theta(1-\lambda)(\Delta^3)^2-\pi_m^2\}}{Q^3} = = \frac{p^3-\pi_r^2-\alpha\Delta\pi_{sc}}{Q^3} \tag{26}$$

by $w^3-w_{\max}=-\alpha\Delta_{sc}/Q^3<0$ and $w^3-w_{\min}=(1-\alpha)\Delta/Q^3>0$, so it is possible to get $w_{\min}<w^3<w_{\max}$, proof after all.

From Proposition 4 and Proposition 5, the increase in the respective increases in the returns of leaders and followers is $\Delta\pi_r^3=\alpha\Delta_{sc}$ and $\Delta\pi_m^3=(1-\alpha)\Delta_{sc}$ respectively, when the optimization results in maximizing the overall returns of the investment.

4. Discussions

In this chapter, it is clear from properties (1), (2) and (4) that the amount of income reduction, the market price, and the benefits to all parties show a clear relationship with the cost coefficients of low-carbon behavior, and this chapter focuses on analyzing the impact of t . Assuming basic market demand is met $a=50$, market demand price sensitivity factor $b=1$, production cost $c=5$, initial amount of disclosure for investment products $e_0=3.8$, low carbon behavior difficulty factor $\theta=50$, compare the effects of trustworthiness t on the price of investment, the volume of investment, the amount of income reduction, the return on investment, and the incremental value of income from investment under the fully cooperative, fully non-cooperative, and cost-sharing decision models.

4.1. The impact of trust on investment prices

The effect of trustworthiness on the investment price is shown in Fig. 1.

From Fig. 1 it is easy to see that the lowest investment price under the fully cooperative decision model, the highest investment price in the fully uncooperative decision model, with the increase in market pressure, low carbon behavior under the three decision models increase in intensity, at this time the investment market is willing to pay higher prices for green investment products, and with the increase in green, the investment under the three decision models The price differential is becoming progressively smaller.

4.2. The impact of confidence levels on investment volumes

The effect of trustworthiness on the volume of investment is shown in Fig. 2, from which it results that, as the degree of green levy gradually increases, the demand among all three game models shows a decreasing trend, mainly because the investment product is overpriced due to the increasing green value, which leads to the loss of a part of the non-environmental market that prefers low prices; at the same time, regardless of the full cooperation or cost-sharing decision, the demand will lead to zero as the degree of green levy increases.

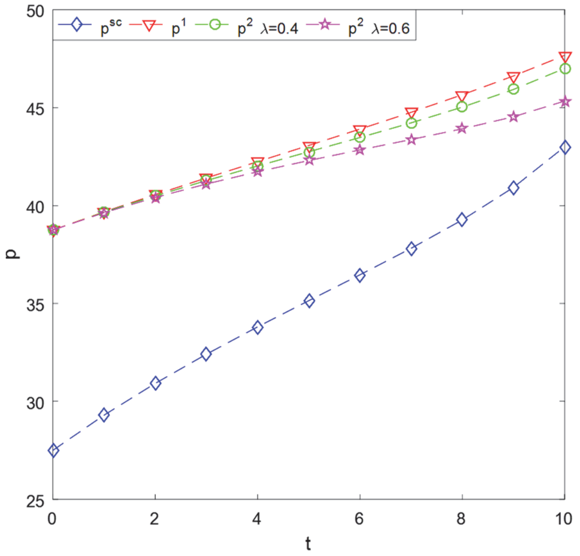

Fig. 1. Impact of changes in value t on investment price p

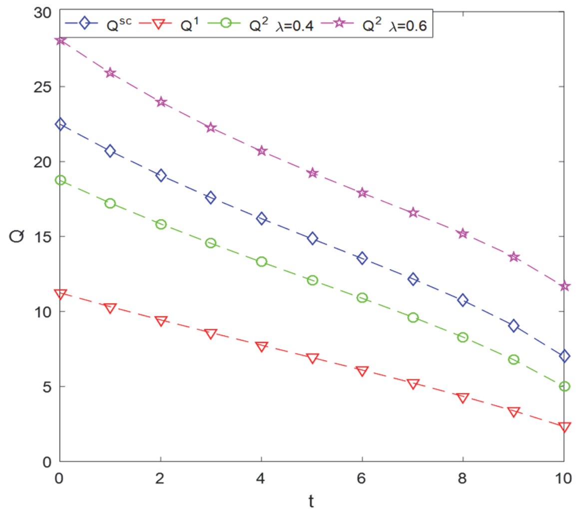

Fig. 2. Impact of changes in value t on investment volume Q

4.3. The impact of trust on the amount of revenue reduction

The effect of trustworthiness on the amount of revenue reduction is shown in Fig. 3. From Fig. 3, it can be seen that the amount of revenue reduction is largest under the fully cooperative decision model at low carbon behavior cost sharing factor λ=0.4; when λ=0.5, the revenue reduction under the fully cooperative decision and cost sharing contract is the same; when λ=0.6, the revenue reduction in the low carbon behavior cost sharing decision model is largest, and the low carbon behavior component sharing factor λ affects the final revenue reduction. At the same time, as market pressure increases, the amount of disclosure in the three models first increases and then decreases in the change situation, so the market is particularly important in the process of setting a reasonable green, to avoid higher confidence leads to higher emissions; from Fig. 3 can easily be concluded that the amount of revenue reduction in the completely uncooperative model is the smallest, cooperative low-carbon behavior is better than the leader alone low-carbon behavior.

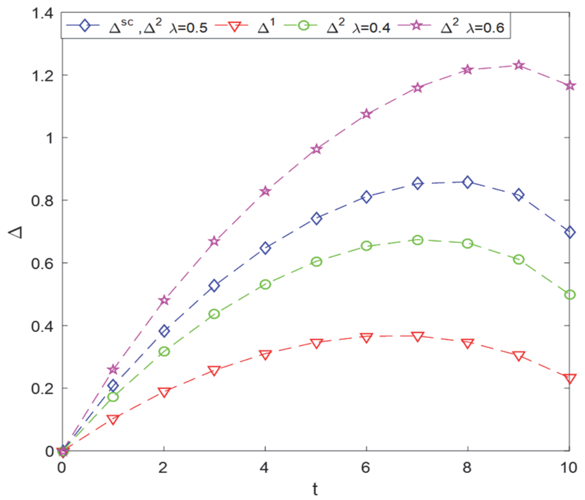

Fig. 3. Impact of changes in value t on income reduction Δ

4.4. The impact of trustworthiness on investment returns

The effect of trustworthiness on the profitability of the investment is shown in Fig. 4. Fig. 4 shows that with the gradual increase in the degree of green levy, the overall profit of the investment among the three game models shows a decreasing trend; from Figs. 1-4, it can be seen that the profit of the investment in the completely uncooperative model and the cost sharing model are less than the total profit of the investment in the completely cooperative model, resulting in the uncoordinated investment. In this paper, we optimize the market price under the totally uncooperative model, which leads to the coordination of investment, and the effect of trust on the coordination mechanism can be obtained from Fig. 5.

4.5. The impact of trustworthiness on the value added of investment returns

The effect of trustworthiness on the value added on investment returns is shown in Fig. 5. From Fig. 5, it is easy to see that by optimizing the market price in the low-carbon behavior cost-sharing model, the total benefit of the investment is increased; at the same time, with the gradual increase in the degree of green levy, the incremental value of the benefit on the investment shows a decreasing trend, because the increase in market pressure, the greater the cost of low-carbon behavior carried out by the enterprise, and thus the relative revenue income of the enterprise becomes smaller.

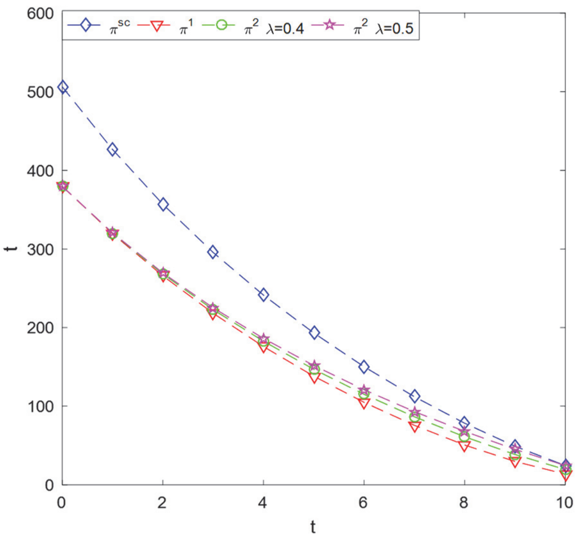

Fig. 4. Impact of changes in value t on investment returns π

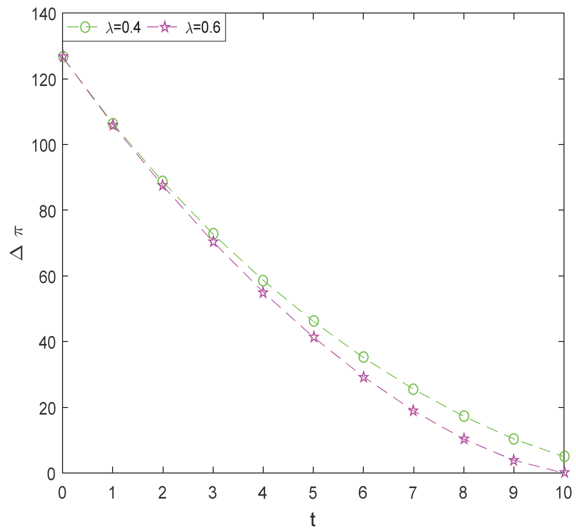

Fig. 5. The effect of changes in value t on the value added to earnings $\Delta\pi$

From the above analysis, it can be seen that there are dual marginal benefits for both the full non-cooperation and cost-sharing contracts, and by optimizing the market price based on the full cooperation decision model for the low-carbon behavior component of the decision model, the gains of leaders and followers on investment are Pareto-optimized regardless of the change in the degree of green levy.

As an important subject of human activities, enterprises are facing challenges from many aspects in assuming responsibility for climate change. On the one hand, the cap-and-trade policies introduced by the government to promote energy saving and emission reduction can affect corporate investment decisions. On the other hand, green technology investment by enterprises can also make traditional investment decisions more complicated. And enterprises are involved in market competition based on interests, and only by standing in the perspective of common interests of leaders and followers to study enterprise investment decision-making behavior, can they maximize their interests by achieving them. In addition, due to the investment process, driven by interests, leaders generally have the behavior of strategic consumers, i.e., concealing green technology inputs and outputs and pursuing profit maximization by means of information disclosure; at the same time, such behavior, followers will also be aware of it, but they do not know about the specific content.

Investment companies take advantage of the macro environment of the investment market to practice social responsibility and increase the common welfare of society, but also to ensure the income and return of the investment team. Although this green invisible investment will increase the cost, but at the same time it also plays a good propaganda effect, the investment company can also ensure the team's return as long as it can do reasonable cost management and cost transfer. From the long-term development of the investment enterprise, or need to do left-handed investment, right-handed public welfare. After all, the long-term development of investment or rely on the power of the market to promote, but also to take into account the interests of followers, whether it is willing to continue to follow or choose to exit.

A truly great enterprise, the way to success is not only the pursuit of profit maximization, but to solve the user pain points around us as the starting point, to create more value for users. Human nature often tends to go for profit, and as an investor must be able to resist the short-term temptation to do something and not to do something, which is an important choice for both investors and entrepreneurs. Therefore, the only way for leaders and followers to avoid short-sightedness is to take the "green concept" into account when making investment decisions together, in order to avoid hollowing out the foundation for future development, eroding the ability to really grow bigger and stronger, and eventually attracting more followers to participate in the investment and all-round support.

5. Conclusions

Conducting low-carbon behavior is one of the main policies in response to changes in the investment market, and market green regulation can be a reasonable constraint on firms to produce low-carbon behavior.

This paper first studies the low-carbon behavior model under the three decisions of complete cooperation, complete non-cooperation and low-carbon behavior cost-sharing on the basis of green, and analyzes the decision problem of leaders and followers; the benefits in both the complete non-cooperation and cost-sharing decision models are smaller than the benefits in the complete cooperation decision, and the investment appears double marginalized utility, by Nash negotiation of the market price in the complete non-cooperation model Optimization results in Pareto optimal gains for both leaders and followers; finally, the model analysis is validated by numerical simulation of the problem.

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