Signaling Game Analysis between Enterprises and Green Investors under Green Bond Financing

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Abstract: Green Bond is a new type of enterprise financing tool. According to the dynamic game characteristics of incomplete information between enterprises and green investors in the process of green bond financing, a signaling game model between enterprises and green investors is constructed, the strategy selection mechanism of both sides and the related influencing factors are obtained. The results show that the disg cost and the discovered risk cost are the main reasons that affect the equilibrium state, and the misjudgment of green investors will also affect the strategic choice of both sides. According to this conclusion, some suggestions are put forward to provide theoretical reference and guidance for enterprises to issue green bonds.

1. Introduction

With the rapid development of global economy, more and more serious environmental problems have been caused, which not only threatens the health of human body and mind, but also restricts the development of society. In March, the 14th five-year plan was officially adopted, and the Party Central Committee, in accordance with the provisions of the Paris Agreement, set out the goal of "Carbon peak, carbon-neutral", which is not only a requirement for high-quality development of China's economy, and a commitment to global climate change. Under the background of double-carbon Target, government departments and mass media have strengthened environmental regulation and green supervision, which leads to the pressure of environmental protection of enterprises [1]. At present, enterprises in the green development, there are financing constraints and insufficient investment and other issues [2]. Enterprises are in urgent need of green finance and other new financial models to promote the green transformation of enterprises. But Green Finance has the characteristics of high uncertainty and long cycle to investors [3]. This makes the development of green finance in China relatively slow, leading to a large number of financial resources to high-energy industries, resulting in excess capacity and environmental pollution. Therefore, in order to develop high-quality economy, China should develop green financial market, for example, encourage enterprises to issue green bonds.

The research on the green bond mainly focuses on the definition and function of the Green Bond. As far as its definition is concerned, green bond is a new type of bond with both environmental and economic benefits [4]. Wang et al. believes that green bond is an important financing tool in green financial market [5]. Pham and Huynh thinks that the "Green" and "Bond" in green bonds will be favored by responsible investors [6]. At the same time, the green bond has the dual function of

financing and environmental protection. Ning et al. has found that green bond financing can boost energy efficiency investments and economic growth [7]. Ana-Belén et al. pointed out that compared with other financing methods, green bonds have a direct financial incentive [8]. Sinha et al. empirically analyzes the impact of green bond financing on environmental and social sustainability [9]. Liu et al. said Green bonds were becoming an important tool for mitigating climate change [10].

There is little literature on Green Bond Investment from the perspective of Game Theory, but many scholars have discussed the investment problem from this perspective, mainly focusing on the Information asymmetry of enterprises and investors. Chakraborty et al. conducted a signal game analysis of the Information asymmetry between firms and investors in terms of product quality. By constructing a signaling game model between managers and investors [11], Schmidt et al. explores the problems of over-investment in low-quality companies and under-investment in high-quality companies [12]. Biglaise and Li believes that intermediaries can alleviate the Information asymmetry problem [13]. Weng and Luo also points out that the Information asymmetry problem in the online lending market can be mitigated by the signaling effect of the guarantee mechanism [14].

Generally speaking, the current research mainly focuses on the definition and function of green bonds, and on the signal game, mainly focuses on the investor's Information asymmetry, and studies the issue of green bonds from the signal game angle, there is less literature on Green signals to investors. This paper will try to construct a dynamic game model with incomplete information for enterprises to issue green bonds, and explore the factors influencing the equilibrium state from the three game equilibria, so as to provide decision support for green investors.

2. Model Setting

Generally speaking, enterprises with a higher level of green development are more likely to raise funds through the green bond market. Therefore, when enterprises issue strong green signals, they tend to issue more green bonds, whereas when enterprises issue weak green signals, access to financing is less likely in the green bond market, where companies tend to issue small amounts of green bonds. However, at present, the development time of green bonds in China is short, and green bonds have been given multiple purposes to promote economic development. As a result, the definition of "Green" is relatively loose, and the scope of use of funds is relatively large, and some enterprises are engaged in speculative purposes, there may be greenwashing [15]. For example, we over-package our green development level, and send out strong green signals to the green bond market by means of publicity, image packaging and selective disclosure. In the CO of the game, the Enterprise has complete information on its green development level, and the green investor has incomplete information on the enterprise's green development level, that is, green investors can not see the actual level of green development of an enterprise when they make investment decisions, only through the green signal issued by enterprises, the scale of green bonds issued and Bayesian Law to judge the level of green development of enterprises. Therefore, the game between enterprises and green investors has the characteristics of incomplete information dynamic game, which is suitable for signal game analysis.

2.1 Game model between enterprises and green investors

In the game model, the firm is the signal sender (s) and the green investor is the signal receiver (R). The green investor hopes to filter out the high-quality enterprise with good management condition through the concept of green environmental protection, so as to reduce the investment risk. Enterprises hope to attract more green investors to invest, so as to obtain more financing funds and promote the development of enterprises.

In the co of the game, s knows his own green development level and chooses his own strategy

according to the type of "Natural" selection. The type of enterprise's green development level = { high green development level (H) , low green development level (L)} , the strategic space of an enterprise = { give a strong green signal and issue green bonds (g) , give a weak green signal and issue green bonds (b)} . After the enterprise chooses a behavior in the strategic space and issa signal, the green investor, as the receiver of the signal, modifies the prior probability according to the signal sent by the enterprise and Bayes rule, thus obtains the posterior probability of the enterprise's green development level, and selects the investment behavior according to it.

2.2 Model assumptions

The dynamic game between the enterprise and the green investor under the circances of Information asymmetry, both sides are bounded rationality, therefore the enterprise and the green investor will take the maximization of their own interests as the goal to make the strategic choice, the assumptions in the game model are as follows:

(1) According to the level of green development of enterprises, enterprises can be divided into high green development level and low green development level (excluding non-green polluting enterprises), and the probability of the two are P_h and P_l respectively. $0 \leq P_h \leq 1$, $0 \leq P_l \leq 1$, and $P_h + P_l = 1$.

(2) the strategic space of enterprises is to send out strong green signals and issue green bonds (g) in large quantities, send weak green signals and issue green bonds (b) in small quantities, obviously $S_g > S_b$.

(3) because different investors have different risk preferences, green investors can be divided into three types: risk-seeking, risk-neutral and risk-averse, the possible investment behaviors of these three types of green investors are: Large Investment, small investment and no investment. Therefore, the strategic space of green investors is a = { large investment (S_g) , small investment (S_b) , no investment (S_0)} . The two kinds of green development level of the enterprise bring to the investor the income is respectively E_g、 E_b. Because the higher the level of green development, the more can promote the stable and sustainable development of enterprises, and bring greater returns to investors, therefore $E_g > E_b$.

(4) generally speaking, when the green development level of an enterprise is high, the return to investors from more investment will be greater than that from investors from less investment when the green development level of the enterprise is low. Therefore, when the enterprise's green development level is high, the investor's income is big, namely $E_g > S_g > E_b > S_b > 0$ and $E_g - S_g > E_b - S_b$.

(5) when P(h|g) and P(l|g) send out strong green signal and issue a lot of green bonds, the probability of their actual green development level is high and low respectively; P(h|g) and P(l|g) have high and low probability of green development when they send out weak green signals and issue a small amount of green bonds. From the practical significance, when the actual level of green development of enterprises is high, enterprises will send out strong green signal. Therefore, P(h|g) = 0, P(h|g) + P(l|g) = 1, and P(l|g) = 1.

(6) a company with a lower level of green development must make a certain amount of false pretences when it sends out a strong green signal. Assuming its cost is C, the company will be punished when it is discovered by the regulatory authorities. The probability of being discovered is f, among them, C can be regarded as the silent cost, Q is the risk cost and f is the risk probability.

(7) because green investors can not fully understand the information of the green development level of enterprises, there is the possibility of misjudgment in the investment process. When the enterprise itself has a certain level of green development, and the investor is wrong, it will affect the

enterprise's green development enthusiasm, increase the opportunity cost of the green investor, at the same time, will bring the additional loss to the investor. Therefore, in order to facilitate the quantitative research, if the Enterprise Green Development level is high, the green investor will choose the small investment, will have the additional loss D. At the same time, it can be assumed $D > S_g - S_b$. That is, when green investors misjudge, the loss will be bigger than the amount of less investment, and when investors choose not to invest, the profit of both enterprises and green investors will be 0

The relevant parameters and implications of the game model can be derived from the above seven assumptions as follows:

Table 1: Parameters and implications of the model

Parameters	Implications
P_h	Probability of high level of Enterprise Green Development
P_l	Probability of low level of Enterprise Green Development
S_g	Send a strong green signal and issue lots of green bonds
S_b	Issue a weak green signal and a small amount of green bonds
E_g	The benefits of high green development level of enterprises to investors
E_b	The benefit of low green development level of enterprises to investors
P(h|g)	The probability of high green development level when enterprises send out strong green signals and issue green bonds in large quantities
P(l|g)	The probability of low green development level when enterprises issue strong green signal and green bonds
P(h|b)	The probability of high green development level when enterprises issue weak green signal and a small amount of green bonds
P(l|b)	The probability of low green development level when enterprises issue weak green signal and a small amount of green bonds
C	The disgd costs of business
Q	The penalty for being caught by the authorities in disg
f	The probability of being discovered in disg
D	Additional losses incurred by green investors who invest in small amounts in enterprises with high levels of green development

2.3 Model analysis

According to the above game model, we can get the income of the enterprise and the green investor under different conditions (the former is the income of the enterprise and the latter is the income of the Green Investor):

a. When green investors choose to invest in large amounts and the enterprises issue green bonds in large quantities, if the actual green development level of the enterprises is high, the profits of the enterprises and green investors are $(S_g, E_g - S_g)$; If the enterprise's green development level is low, the enterprise and the green investor's income are $(S_g - C - fQ, E_g - S_g)$ respectively.

b. When Green investors choose to invest in small amount and the enterprise sends out strong green signal and issa lot of green bonds, if the level of green development of the enterprise is high, the income of the enterprise and the green investor is $(S_b, E_g - S_b - D)$; The return for a business and a green investor is $(S_b - C - fQ, E_b - S_b)$.

c. From the practical significance, only when the level of green development is low will the enterprises send out weak green signals and issue a small number of green bonds. When green

investors see the choices made by the enterprises, they will inevitably adopt the strategy of small investment, the income of enterprises and green investors is $(S_b, E_b - S_b)$ respectively; conversely, weak enterprises with high green development level will not send out weak green signal and only issue a small number of green bonds for financing.

d. When the green investors take the no-investment strategy, if the enterprise's green development level is low but chooses to send out the strong green signal, then the enterprise and the green investor's income are respectively $(-C - fQ, 0)$, in other cases, no matter how high or low the level of green development of enterprises or what kind of strategies they adopt, the income of enterprises and green investors in this dynamic game is 0, that is (0,0) .

Therefore, the game between enterprises and green investors can be expanded as follows:
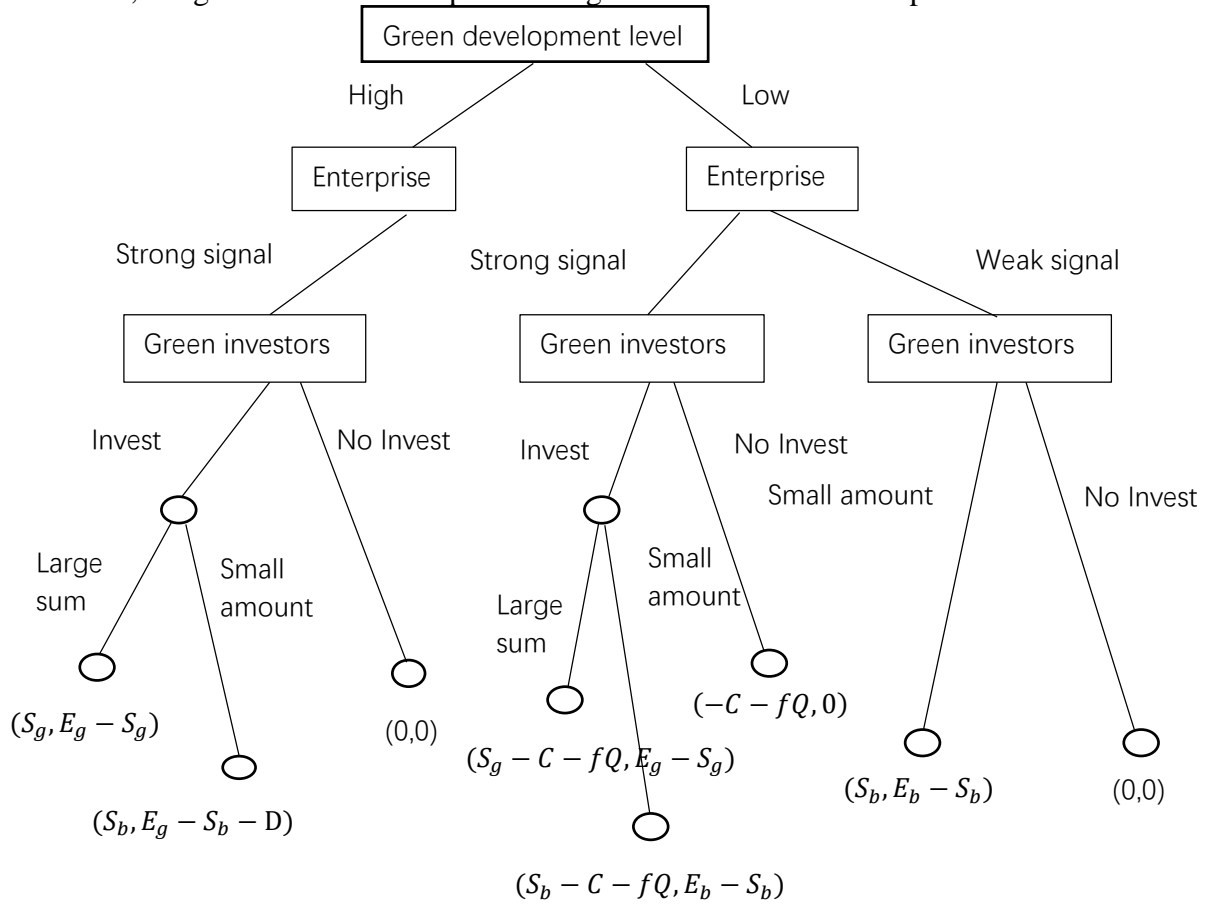

Figure 1: Expansion of the game between enterprises and investors

As can be seen from figure 1, when a company has a high level of green development, it will send out a strong green signal and issue a large number of green bonds, green investors will choose the three strategies of large investment, small investment and no investment according to the relevant information. When the level of green development of enterprises is low, enterprises will send out weak green signals and issue a small number of green bonds, but it may also be interfered by factors such as speculation and choose camouflage, thus sending a strong green signal, at this time, green investors will face three strategies.

Thus, the expected return of green investors when they adopt a large investment strategy is:

$$E_1 = P(h|g)(E_g - S_g) + P(l|g)(E_b - S_g) \tag{1}$$

The expected returns for green investors when they adopt a microinvestment strategy are:

$$E_2 = P(h|g)(E_g - S_b - D) + P(l|g)(E_b - S_b) + P(l|b)(E_b - S_b) \qquad (2)$$

The expected return of a green investor on a no-investment strategy is:

$$E_3 = P(h|g) * 0 + P(l|g) * 0 + P(l|b) * 0 = 0 \qquad (3)$$

3. Equilibrium analysis

In this dynamic game process, if the green investors will adopt the same strategy regardless of whether the green development level of the enterprises is high or low, then the situation of mixed equilibrium may occur, the strategies adopted by green investors will be correspondingly different, and the situation of separation and equilibrium may occur. In this analysis, the strategic choices of both players are described as: [(the strategic choice of high green development level, the strategic choice of low green development level), (the strategic choice of green investors 1, the strategic choice of green investors 2)]

3.1 Market completely successful seperation equilibrium

If $S_g - C - fQ < S_b$, and P(h|g) is large enough, and P(l|g) is small enough, that is, the cost of the enterprise's disg is larger than the cost of the risk discovered by the regulatory authorities, at this time, enterprises will issue green signals and bonds according to their actual level of green development, that is, to form a perfect Bayesian equilibrium of complete market success:

(1) Enterprises with a high level of green development issue strong green signals and a large number of green bonds, while those with a low level of green development issue weak green signals and a small number of green bonds;

(2) Green investors will adopt appropriate strategies according to the signals issued by enterprises;

(3) The judgment of green investors is P(h|g) = 1, P(l|g) = 0, P(h|b) = 0, P(l|b) = 1.

This equilibrium can be proved by backward induction:

1) For green investors, when companies send a strong green signal and issue lots of green bonds,

If the green investor chooses the large investment, then the green investor's expected return is: $E = E_1 = E_g - S_g$;

If the green investor chooses the small investment, then the green investor's expected return is: $E = E_2 = E_g - S_b - D$;

If the green investor chooses not to invest, then the green investor's expected return is: $E = E_3 = 0$.

As $E_g > S_g$ and $D > S_g - S_b$ we know that $E_1 > E_2, E_1 > E_3$, so green investors will inevitably take a large investment strategy at this time.

When companies send a weak green signal and issue small amounts of green bonds,

Green investors are not going to make big investments based on this signal from their companies;

If the green investor chooses the small investment, then the green investor's expected return is: $E = E_2 = E_b - S_b$;

If the green investor chooses not to invest, the green investor's return is: $E = E_3 = 0$.

From the above $E_b > S_b$, therefore $E_2 > E_3 = 0$, at this time green investors will inevitably take a small investment strategy.

2) for an enterprise, if the green development level of the enterprise is high, the enterprise will send out a strong green signal and issue a large number of green bonds; conversely, if the green development level is low, when the enterprise sends a strong green signal and issue a large number of green bonds, its income is $S_g - C - fQ$, when the enterprise sends a weak green signal and issa small number of green bonds, its income is S_b, from $S_g - C - fQ < S_b$, the enterprise will adopt a

strategy of sending a weak green signal and issuing a small number of green bonds.

Through the above analysis, we can see that under the case of $S_g - C - fQ < S_b$, the market can achieve a completely successful separation equilibrium, that is, when the enterprise's camouflage cost of pretending to be green and the risk cost of being discovered are higher, the signals sent by enterprises are consistent with the real situation, and green investors will choose the corresponding investment strategy according to the signals sent by enterprises. This equilibrium can not only provide effective financial support for enterprises, but also can screen out high-quality green enterprises for green investors, reduce investment risks and achieve a win-win situation.

3.2 Partially successful market equilibrium

If $S_g - C - fQ > S_b$, and P(h|g) is large enough, P(l|g) is small enough, that is, The camouflage cost of the enterprise and the risk cost discovered by the supervision department are small, But Green investors believe that companies that send strong green signals actually have a high level of green development, which would constitute a perfect Bayesian equilibrium for the success of some segments of the market:

(1) regardless of the level of green development, enterprises will send out strong green signals and issue a large number of green bonds;

(2) green investors will adopt a large investment strategy based on the strong green signals issued by enterprises;

(3) the green investor's judgment is that $P(h|g) = P(h), P(l|g) = P(l)$, P(h) is large.

This equilibrium can be proved by backward induction:

1) for green investors, when companies send a strong green signal and issue lots of green bonds,

If Green investors choose large investment, then the expected return of green investors is: $E = E_1 = P(h|g)(E_g - S_g) + P(l|g)(E_b - S_g)$;

If the green investor chooses the small investment, then the green investor's expected return is: $E = E_2 = P(h|g)(E_g - S_b - D) + P(l|g)(E_b - S_b)$;

If the green investor chooses not to invest, then the green investor's expected return is: $E = E_3 = 0$.

Since $P(h|g) = P(h)$ is large and $P(l|g) = P(l)$ is small, the postfactorial terms of E_1 and E_2 can be ignored, so $E_1 = P(h|g)(E_g - S_g)$. And Because $D > S_g - S_b$ and $E_g > S_g$ we can know that $E_1 > E_2$ and $E_1 > E_3$, green investors must choose large investments at this time.

2) for companies, as a result of $S_g - C - fQ > S_b$, regardless of the actual level of green development, companies will choose to send a strong green signal and issue a large number of green bonds.

Based on the above analysis, it can be seen that there will be a successful merger equilibrium of market segment when $S_g - C - fQ > S_b$ is established, that is, when the camouflage cost of pretending to be green and the risk cost of being discovered are lower, whatever their level of green development, companies send out strong green signals and issue lots of green bonds; for green investors. In such a market, some enterprises with a lower level of green development will disg themselves for speculative purposes, because the losses of Misjudgment D are large, and green investors will tend to adopt the strategy of making large investments, therefore, there is a certain "Free rider" phenomenon, but overall, the majority of enterprises have a higher level of green development, in the case of large probability, both enterprises and green investors can benefit.

3.3 Partially successful market equilibrium

If $S_g - C - fQ > S_b$, and P(l|g) is big enough, and P(h|g) small enough, that is, the cost of

disg is small compared with the cost of risk discovered by the regulatory authorities, all enterprises will send out a strong green signal, at this time, the behavior of enterprises can not reflect the true level of green development at all. Green investors tend to think that the general level of green development of enterprises in the market is low, so they will adopt the strategy of small investment, a perfect Bayesian equilibrium of partial market success:

(1) Regardless of the level of green development, enterprises will send out strong green signals and issue a large number of green bonds;

(2) Green investors will adopt a micro-investment strategy;

(3) The green investor's judgment is $P(h|g) = P(h), P(l|g) = P(l)$, P(l) is big, P(h) is small.

This equilibrium is proved by backward induction:

1) For green investors, when companies send a strong green signal and issue lots of green bonds,

If Green investors choose large investment, then the expected return of green investors is: $E = E_1 = P(h|g)(E_g - S_g) + P(l|g)(E_b - S_g)$;

If the green investor chooses the small investment, then the green investor's expected return is: $E = E_2 = P(h|g)(E_g - S_b - D) + P(l|g)(E_b - S_b)$;

If the green investor chooses not to invest, the green investor's expected return is: $E = E_3 = 0$.

Since $P(h|g) = P(h)$ is small and $P(l|g) = P(l)$ is large, the antecedents of E_1 and E_2 can be ignored, we can know that $E_1 = P(l|g)(E_b - S_g)$, $E_2 = P(l|g)(E_b - S_b)$. And because $S_g > S_b$ and $E_b > S_b$, $E_1 < E_2$ and $E_2 > E_3$, so green investors must choose small investments at this time.

2) for enterprises, if the level of green development is high, it will send out a strong green signal and issue a large number of green bonds; If the level of green development is low, the profit of enterprises sending out strong green signals is $S_g - C - fQ$, the payoff from a weak green signal is S_b, From $S_g - C - fQ > S_b$, regardless of the actual level of green development, enterprises will choose to send a strong green signal and issue a large number of green bonds

Based on the above analysis, it can be seen that there will be a successful merger equilibrium of market segment when $S_g - C - fQ > S_b$ is established, that is, when the camouflage cost of pretending to be green and the risk cost of being discovered are lower, regardless of the type of green development level of the enterprise, the enterprise will send out a strong green signal and issue a large number of green bonds, and green investors have grasped this information and made a judgment that most enterprises will be affected by the psychology of speculation, thus masquerading as a high-level green business, green investors will only make small investments rather than large ones. Under such circances, enterprises with a high level of green development will find it difficult to obtain sufficient financing funds from the green bond market, which will discourage enterprises'enthusiasm and, in the long run, be detrimental to the stable development of enterprises, paying extra camouflage costs, taking more risks, but not being able to trick investors into making big investments, instead increasing the cost of the business and causing unnecessary waste of funds; for Green Investors, in the long run, the overall development of the enterprises in the market will be hindered, and the investment income of the green investors will be reduced, and both sides of the game can not get good income.

4. Conclusions and recommendations

Based on the signaling Game Theory, this paper analyzes the influencing factors of corporate financing through Green Bonds, discs the strategic choices of corporate and green investors in three cases, and draws the following conclusions:

(1) The optimal state is that when the camouflage cost and the risk cost of the enterprise are large, the rational enterprise will not choose the camouflage at this time, thus avoiding the possibility of the green investor misjudging the green development level of the enterprise, the two sides of the game will achieve a completely successful market equilibrium, enterprises and green investors can benefit

from the transaction process, to achieve a win-win effect.

(2) The worst case scenario is that firms in all markets will send out strong green signals and issue lots of green bonds when their camouflage and risk costs are low, and in the long run, green investors will lose confidence in the business and believe that all the businesses in the market are not good quality enterprises for investment. At this time, the green investors will not invest any more and their investment returns will be zero, it also bears the cost of camouflage and the risk of being found out, with negative returns, at which point the green bond market will run out of liquidity and risk of stagnation.

(3) The misjudgment of green investors on the level of green development of enterprises is also an important factor affecting the financing of enterprises issuing green bonds. At present, in China's Green Bond Market, investors' cognitive bias is relatively large, due to the lack of relevant knowledge and quality of learning, green investors are easily influenced by public opinion and show two extremes of overconfidence and conservatism, which is not only disadvantageous to corporate financing, but also has an impact on investors' own income.

Based on the above conclusions, this paper points out the need to improve the green bond market in China, and pforward the corresponding recommendations:

(1) The government should regulate the issuance of green bonds by enterprises, focusing on the authenticity of green projects declared by enterprises and the flow of funds raised by green bonds, and formulate relevant laws and regulations, to increase the punishment of illegal behavior, so as to increase the risk cost of enterprise camouflage, inhibit excessive speculation, and enhance the confidence of green investors.

(2) Enterprises should establish a correct concept of financing, abide by market norms, reduce speculative mentality, focus on the quality of products and services, through green innovation, effectively improve their level of green development, in order to attract more green investors at the same time enhance the enterprise green reputation and environmental benefits.

(3) Green investors should keep calm and rational, constantly learn and accumulate investment experience, in contact with advertising and public opinion, adhere to independent thinking, in-depth research, try to avoid herd behavior and overconfidence; At the same time, attention should be paid to avoid the conservative thought caused by loss aversion, so as to reduce the extra loss caused by misjudgment.

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