

Original Research

Give a Hand or a Tournament? The Impact of Green Investment on Corporation ESG Commitment and Greenwashing

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Abstract

The ESG framework has made a substantial contribution to environmental sustainability, with corporate ESG performance increasingly being recognized as a key factor in green investment decisions. However, intensifying competition among corporations to pledge low-carbon initiatives, aiming to attract limited green investments, has transformed ESG commitments into a competitive tournament. This suggests that a corporation's public commitment to sustainability often supersedes its actual environmental actions in securing green investments. Despite the scrutiny of ESG commitments, a discrepancy risk persists between these commitments and their actual performance, such as greenwashing. This study develops a principal-agent comparative model to investigate the mechanisms and impacts of green investment decisions that are based on commitments and actual outcomes. The analysis reveals that the efficiency of commitment-based investments hinges on the investor's capacity for verification, with an essential threshold of accuracy for policy effectiveness. This verification process becomes significantly more important when companies derive greater profits from green investments. Unlike outcome-based investment strategies, commitment-based approaches may result in lower levels of carbon reduction by companies. However, they enable investors to curtail non-productive expenditures and enhance capital utilization efficiency. Consequently, the potential of commitment-based investments to enhance overall societal benefits depends on the accuracy of verification and its associated costs.

Keywords: ESG report, green investment, sustainability commitment, incentive compatibility

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Introduction

A corporation's efforts towards low-carbon production reflect its attitude toward environmental responsibilities.

Before the widespread adoption of ESG (Environmental, Social, and Governance) commitment systems, corporations typically demonstrated their environmental attitude through post-hoc carbon emission data. The launch of the United Nations-supported Principles for Responsible Investment (PRI) in 2006 marked the onset of the global popularity of ESG disclosures. These principles not only require corporations to disclose their ESG plans and actions, but also encourage investors to incorporate ESG factors into their investment decisions [1].

In recent years, environmental consciousness has significantly increased across society [2-4]. With growing public concern over climate change and sustainable development, ESG commitments are increasingly viewed as representative of a corporation's willingness to pursue sustainable development, despite many being based on pre-commitments. On one hand, there is a growing trend among consumers to willingly pay higher prices for green products [5, 6]. On the other hand, studies have substantiated the benefits of investing in ESG-committed enterprises for both businesses [7] and society [8], leading to a marked preference in green investments for companies that make ESG commitments [9, 10]. Furthermore, in countries where voluntary ESG disclosures by corporations are encouraged, governments are offering more accessible financing channels to these entities [11].

The original intention of green investors and governments to generously support corporations with ESG commitments is commendable and has successfully led to an increased corporate focus on environmental issues [12, 13]. Driven by additional benefits, corporations are increasingly eager to publicly commit to their ESG agendas, aiming to reap associated benefits from these commitments, such as market access and low-interest loans [14, 15]. However, the competition for limited green investments, through announcements of low-carbon commitments, has transformed ESG commitments into a competitive tournament [16, 17]. Some corporations are strategically adopting ESG commitments and disclosures to gain advantages typically reserved for low-carbon enterprises [18]. Despite the oversight and auditing of corporate ESG commitments by professional organizations, it must be acknowledged that the rise of the ESG tournament has led investors to shift their focus from paying for outcomes to paying for commitments [19].

Consequently, corporations are at risk of losing investment opportunities if they fail to make ESG commitments that appear more appealing to investors than those of their competitors, regardless of whether they will substantiate their environmental stance with post-hoc carbon emissions data [20]. As a result, there

is an inevitable tendency for some corporations to make exaggerated or false claims about the environmental or social benefits of their products or services in their ESG disclosures [21]. A typical example of this is 'greenwashing' [22, 23], where corporations mislead consumers about their environmental performance or the environmental benefits of their products or services [24], despite not making the efforts they claim to [25], and in some cases there is even no significant correlation between a corporation's ESG commitments and its actual environmental stance [26, 27]. Even worse, there arises an issue of adverse selection: corporations that are more inclined to make ESG commitments tend to have worse environmental reputations [28] and higher pollutant emissions [29] as they attempt to enhance their societal image through false commitments.

In light of these issues, a decision-making dilemma has emerged: should green investors adopt a commitment-based investment strategy? Public disclosure of ESG information, serving as a vital mechanism for signal transmission, has the potential to mitigate principal-agent problems stemming from information asymmetry. However, there is a concurrent risk that companies with low ESG performance might issue falsified ESG reports to garner benefits. Therefore, this study focuses on the effectiveness of a decision-making model that hinges on ESG commitments for societal benefits and its consequent impact on both parties' decision-making.

Current research on the mechanisms and impacts of commitment-based ESG investment decisions is still emerging. Laharish [30] used a competitive dynamics perspective to examine inter-firm ESG rivalry, while Evangelos [31] explored the competitive effects of ESG using a computational model through computational experiments. However, there remains a lack of comprehensive, forward-looking, and specialized systematic studies in this field. This study contributes by starting with an analysis of the processes and characteristics of the commitment-based investment decision mode and constructing a comparative model that ensures incentive compatibility between investors and corporations. Furthermore, this research delves into the incentives for information distortion by corporations during the commitment-based mode. Additionally, we examine the impact of investor verification on the strategies and benefits of both parties within a hierarchical relationship, offering mathematical and model-based support for investment decisions.

The remainder of this paper is organized as follows: Section 2 offers a theoretical review and presents the research hypotheses. Section 3 introduces the research model used in this study. Section 4 derives and discusses the primary conclusions. Section 5 provides the overall research findings and corresponding interpretations, while Section 6 explores the impact of this study in the ESG area and outlines directions for future research.

Theoretical Review and Research Hypotheses

Theoretical Review

The study of investment strategy fundamentally involves contrasting the operational dynamics of a project under commitment-based and outcome-based modes. When a project represents the interests of superiors but its success hinges on the efforts of subordinates, a potential misalignment of interests between these two parties can arise [32]. Subordinates might prioritize their personal interests, thereby not fully committing to the project's objectives. In such scenarios, a significant challenge is to design effective institutional mechanisms that align the actions of subordinates with the goals of superiors [33]. The principal-agent model is designed to examine decision-making and incentive issues within this framework. It is extensively utilized in academic research to analyze strategic choices, assess incentive constraints, and design optimal contracts [34]. This model offers valuable insights into how different investment strategies, such as commitment-based and outcome-based modes, can influence the alignment of interests between different hierarchical levels within an organization or a project.

Principal-agent theory, as a fundamental aspect of contract theory, has garnered increasing scholarly attention since the early 1970s, particularly in the context of information asymmetry and incentive issues. This focus aims to demystify the 'black box' mechanisms operating within firms. At its core, the principal-agent model seeks to unravel how, in scenarios marked by conflicting interests and information asymmetry, a principal (such as an investor) can devise optimal contracts or guidelines to effectively influence or regulate the behavior of an agent (such as a corporation) [35]. Sappington [36] further elaborated on this theory by outlining its basic procedural framework: initially constructing an agency problem based on the assumptions of conflicting interests and information asymmetry; subsequently identifying the inherent constraints of the problem; and finally, determining the decisions the principal needs to make to maximize utility. This structured approach offers a systematic method for analyzing and resolving the complexities inherent in principal-agent relationships.

In the investigation of incentive behaviors and strategic responses within hierarchical principal-agent relationships, game theory research emerges as the most prevalent and effective methodology [37]. Including commitment mechanisms, scholars have been using game theory to find methods that enhance performance in bureaucratic systems. Jayasekara [38] utilized game theory to characterize the principal-agent relationship between bank managers and employees, seeking ways to maximize overall corporation profits while minimizing costs. Chen [39] explored the feasibility of resolving information asymmetry and

moral hazard issues in principal-agent problems through new technologies. Kjell [40] applied principal-agent theory and game theory to the Precautionary Principle to investigate changes in utility.

In theoretical research concerning ESG (Environmental, Social, and Governance) and CSR (corporate Social Responsibility) and their impact on social benefits, equal attention is given to the exchange of information and signaling between hierarchical levels: Gimpel [41] used game theory methodologies to study how organizations ultimately decide to incorporate sustainability into their strategic planning to gain advantages. Friedrich [42] examined the strategic use of corporate social responsibility (CSR) in Cournot competition and showed that the more efficient firm chooses a higher CSR level, reinforcing its dominant position. Uyar [43] explored the validity of the signaling theory and the greenwashing tendency in the logistics sector. Nirino [44] suggested that, from a corporation's structural perspective, ESG practices are important for addressing stakeholders' needs.

In summary, given the widespread application of the principal-agent model in related fields, its capability to elucidate the motivations of both hierarchical levels, and its effectiveness in determining optimal strategies under resource constraints [45], this paper adopts this model to delve into the effects and mechanisms of commitment-based investment strategy. Our objective is to offer a novel theoretical perspective for research applications in relevant areas. By doing so, we aim to contribute to a deeper understanding of these complex investment dynamics and assist in guiding more informed decision-making in the realms influenced by these strategies.

Research Hypotheses

In their interactions with investors, corporations may, at times, engage in deceptive practices. These deceptive practices can include exaggerating the use of green materials, concealing environmentally harmful production processes, or presenting products in a misleading manner. These actions are primarily driven by the corporation's desire to appear more favorable than other companies in the 'commitment competition' to secure green investments or other resources. The more intense the competition, the stronger the motivation for corporations to engage in deception [46], and this phenomenon can be attributed to the higher embeddedness of environmental commitments in these contexts.

The commitment-based mode fundamentally differs from the outcome-based mode in terms of the timing and focus of their impact. While the outcome-based mode takes effect only after the completion of a project, assessing its success or failure based on tangible results, the commitment-based mode plays a critical role at the project's initiation phase. It directly influences whether a project receives the green light, with commitments often serving as a key determinant in securing necessary

support and resources. Given the high embeddedness of the commitment-based mode and the information asymmetry between different levels, it is more prone to information distortion [47]. Based on this, we propose Hypothesis 1:

- **Hypothesis 1:** The commitment-based mode functions as a significant medium for signal transmission. It can carry the corporation's genuine commitment to the level of carbon footprint reduction of the project or their exaggerated false commitment to the level for additional benefits.

When investors discover that a corporation has falsified its commitments, they too will implement punitive measures. These sanctions may manifest as withdrawal of investments, a decline in stock prices, or damage to the corporation's reputation. Investors typically rely on the information provided by corporations to make investment decisions; therefore, when such information is proven to be false, this breach of trust can lead to severe consequences [48]. Furthermore, whether in outcome-based or commitment-based mode, investors will still compare a corporation's performance commitments to actual outcomes, regardless of whether it may impact their investment decisions. When the disparities are significant, investors may still take actions such as divestment or selling stocks [49], resulting in losses for the corporation.

Based on the above facts, we propose Hypothesis 2 and Hypothesis 3:

- **Hypothesis 2:** In the commitment-based mode, when the corporation is found by the investor to have made a false commitment or distorted information, the corporation must face corresponding penalties such as disinvestment.
- **Hypothesis 3:** Both in the commitment-based mode and the outcome-based mode, when there is a significant gap between the actual outcomes

and commitment, the corporation must face corresponding penalties.

Model Definition and Construction

Design of the Game Model Process

Consider a project designed to generate societal benefits, operating within a principal-agent framework that encompasses two hierarchical levels. At the upper level of this hierarchy is the investor, who faces a critical decision: choosing between an outcome-based and a commitment-based investment mode. The outcome-based mode relies on evaluating the project's results post-completion, while the commitment-based mode focuses on upfront commitments made regarding the project's goals and methodologies.

Outcome-Based Mode

In the outcome-based investment mode, the subordinate (corporation) is responsible for the implementation of the project and reports the output results to the superior (investor) upon project completion. Based on the post-implementation outcomes, the investor rewards or penalizes the corporation.

Commitment-Based Mode

In the commitment-based investment mode, the corporation is responsible for the implementation of the project. However, before the project's execution, the corporation must promise the project's scale and predetermined level of carbon footprint reduction to the investor. The investor verifies this information, penalizes any distortion of information, and decides

Table 1. Symbols and Definitions of Main Variables and Parameters.

Symbols	Definitions	Symbols	Definitions
i	Level of carbon footprint reduction in the project	b_{is}^*	Optimal solution for the corporation's cost coefficient under complete information
e	Scale of the project	π_{hs}^*	Social benefits of the project under complete information
$c(i, e)$	corporation cost	w_{is}^*	Optimal solution for the investor's fixed costs under complete information
b_i	corporation's cost coefficient based on low-carbon level	b_{ip}^*	Optimal solution for the corporation's cost coefficient in an outcome-based mode
$r_i(e)$	Amount of investment	π_{hp}^*	Social benefits of the project in an outcome-based mode
β_i	Investor's investment coefficient based on low-carbon level	w_{ip}^*	Optimal solution for the investor's fixed costs under outcome-based mode
w_i	Fixed costs for the investor	b_{ix}^*	Optimal solution for the corporation's cost coefficient in a commitment-based mode
$p(i)$	Profit situation of the project for the corporation	π_{hx}^*	Social benefits of the project in a commitment-based mode
		w_{ix}^*	Optimal solution for the investor's fixed costs under commitment-based mode

whether to fund based on the commitment by the corporation and the verification activities by themselves. Once approved and the project completed, the corporation reports the output results to the investor, who then rewards or penalizes the corporation based on the post-implementation outcomes.

Symbols and Definitions

The symbols used in the model in this article are defined as shown in Table 1.

The Model

In our model, a corporation project is characterized by two key indicators: quantity (scale) and quality (level of carbon footprint reduction [50]). The scale of the project, denoted as e , is public information, observable by both the corporation and the investor. In contrast, the level of carbon footprint reduction chosen by the corporation, denoted as i , is private information that the investor cannot directly observe. This distinction between public and private information introduces a layer of complexity in the investor's decision-making process, as it requires reliance on indirect signals or assessments to gauge the actual environmental impact of the project.

For the same project, different low-carbon-quality materials will have different cost coefficients, denoted as b . Let's define $c(i, e)$ as the cost incurred by the corporation to complete a project of scale e with a low-carbon quality i .

$$c(i, e) = \frac{1}{2} b_i e^2 \quad (1)$$

Note: For all $j > i$, it holds that $b_j > b_i$.

Similarly, the investor funds the project. For the same project, different low-carbon qualities will adopt different investment coefficients, denoted as β . Define $r_i(e)$ as the amount of investment for a project of scale e with low-carbon quality i :

$$r_i(e) = w_i + \beta_i e \quad (2)$$

Note: For all $j > i$, it holds that $\beta_j > \beta_i$. Where w_i represents the startup cost under the low-carbon quality i and $\beta_i e$ represents the operational cost related to the project scale under that quality.

For the corporation, in addition to the incentives from the investor, it can also obtain benefits $p(i)$ (such as industry reputation, consumer favor, etc.) by working hard on the project. In summary, the investment, the corporation's effort cost, and the corporation's benefits from the project together constitute the corporation's objective function π_i :

$$\pi_i(i, e) = r_i(e) + p(i) - c(i, e) \quad (3)$$

For the investor, the target is to maximize the social benefits brought by the project, mainly reflected in maximizing the difference between the project's output results and the amount of investment. Without considering uncertainty, under the low-carbon level i , the benefit output of the project is directly proportional to the scale of the project. Therefore, the output results can, without loss of generality, also be represented by e . In this model, the objective function π_h for the investor can be expressed as:

$$\pi_h(i, e) = e - r_i(e) \quad (4)$$

Optimal Solution of the Model

Complete Information Scenario

First, we examine the optimization results of this model under the ideal scenario of complete information. This approach establishes a comparative benchmark, providing a foundational understanding of the model's behavior and outcomes in a theoretically perfect information environment.

In this scenario, the investor can both know the scale e of the project and the low-carbon level i chosen by the corporation for the project. Then the only constraint for Formula (4) is the non-negative utility of the corporation. Therefore, the optimization problem can be transformed into:

$$\begin{aligned} \max \pi_h(i, e) &= e - r_i(e) \\ \text{s. t. } \pi_i(i, e) &\geq 0 \end{aligned} \quad (5)$$

By incorporating Formulas (1), (2), and (3), we can construct the Lagrangian function:

$$L(b_i, \beta_i) = e - w_i - \beta_i e - \lambda \left(w_i + \beta_i e + p(i) - \frac{1}{2} b_i e^2 \right) \quad (6)$$

And

$$\begin{cases} \beta_{is}^* = 0 \\ b_{is}^* = \frac{1}{e} \end{cases} \quad (7)$$

Under the condition of complete information, the optimal social benefit is:

$$\pi_{hs}^*(i, e) = \frac{e}{2} + p(i) \quad (8)$$

Where

$$w_{is}^* = \frac{e}{2} - p(i) \quad (9)$$

Incomplete Information Scenario Based on Outcome-Based Mode

In the outcome-based mode, corporations are also required to report their low-carbon targets to investors. However, the reporting stage in the outcome-based approach does not directly influence the investment decisions of the investor. The investor only evaluates the project based on the outcomes. But if there is a significant discrepancy between the commitment and the outcome (for instance, a commitment of j and an outcome of i , the investor will penalize the corporation by $u(j-i)$ such as disinvestment, where $u(0) = 0$).

Given that $\pi_l(j,e) > \pi_l(i,e)$ for all $j > i$, the corporation has an incentive to declare the level of carbon footprint reduction of the project i as j . Define $\pi_l(i,j)$ as the utility:

$$\pi_l(i,j) = \pi_l(j,e) - u(j-i) \quad (10)$$

Under these circumstances, the objective function for the investor $\pi_h(i,e)$, can be expressed as:

$$\begin{aligned} \max \pi_h(i,e) &= e - r_i(e) \\ \text{s.t. } 1 \quad \pi_l(i,e) \geq \pi_l(i,j) \geq 0, \quad e &= \operatorname{argmax} \pi_l(i,j) \end{aligned} \quad (11)$$

Where

$$\begin{aligned} \max \pi_h(i,e) &= e - r_i(e) \\ \text{s.t. } 1 \quad \pi_l(i,e) \geq \pi_l(i,j) \geq 0, \quad e &= \operatorname{argmax} \pi_l(i,j) \end{aligned} \quad (12)$$

And

$$\begin{cases} \beta_{jp}^* = 1 \\ b_{ip}^* = \frac{1 - u'(j-i)}{e} \end{cases} \quad (13)$$

The optimal social benefit under the scenario of an outcome-based mode with incomplete information can be derived as:

$$\pi_{hp}^*(i,e) = \left(1 - \frac{A}{2}\right)e + p(i) \quad (14)$$

Where

$$w_{ip}^* = \frac{A}{2}e - p(i) \quad (15)$$

Note: $A = 1 - u'(j-i)$.

Incomplete Information Scenario Based on Commitment-Based Mode

In the commitment-based mode, the corporation is required to make a commitment about the low-carbon level i before receiving funding for the project. The investor assesses the probability of the project's

approval based on the project scale submitted by the corporation and the proposed level i . In this model, the higher the level proposed by the corporation, the higher the probability of getting the investment. That is, for all $j > i$, the probability with low-carbon level j , $P(j)$, is greater than the probability with level i , $P(i)$. This system inherently incentivizes corporations to propose higher levels of carbon footprint reduction in their commitments to increase the probability of receiving funding. Define the benefit coefficient resulting from the difference in

probabilities as $F(j-i) = \frac{\pi_l(j)}{\pi_l(i)}$, where $F(0) = 1$.

As previously discussed, to tackle potential distortions in the information about the project's carbon footprint reduction level, the investor undertakes a crucial step: a preliminary review of the commitment materials submitted by the corporation. If the corporation distorts information (exaggerating the low-carbon level of i to $j > i$), there is a probability $\rho(j)$ that the investor will detect this. In such cases, the investor will be penalized with an intensity of $v(j-i)$, where $v(0) = 0$. Additionally, similar to the outcome-based mode, if there is a significant discrepancy between the commitment and the outcome, the investor will penalize the corporation with $u(j-i)$.

Given this context, the expected objective function for the corporation, when declaring the low-carbon level i as j , can be represented as $E[\pi_l(i,j)]$:

$$\begin{aligned} E[\pi_l(i,j)] &= F(j-i)[(1-\rho(j))\pi_l(i,j) \\ &+ \rho(j)(\pi_l(i,j) - v(j-i)) - u(j-i)] \end{aligned} \quad (16)$$

The incentive compatibility condition that ensures the corporation truthfully reports to the investor is:

$$\pi_l(i,e) \geq E[\pi_l(i,j)] \quad (17)$$

By substituting Formulas (1) to (4), the incentive compatibility condition can be reformulated as:

$$\begin{aligned} \pi_l(i,e) &= F(i-i)[w_i + \beta_i e + p(i) - c(i,e)] \\ &\geq E[\pi_l(i,j)] = F(j-i)[w_j + \beta_j e + p(j) \\ &- c(j,e) - \rho(j)v(j-i) - u(j-i)] \end{aligned} \quad (18)$$

Define:

$$\begin{aligned} \Pi(x,y) &= F(y-x)[w_y + \beta_y e + p(y) \\ &- c(y,e) - \rho(y)v(y-x) - u(y-x)] \end{aligned} \quad (19)$$

Formula (18) can be reformulated as:

$$\Pi(i,i) \geq \Pi(i,j) \quad (20)$$

Specifically, $\Pi(x,y)$ represents the benefit that the investor needs to achieve through institutional design to satisfy the incentive compatibility condition when

the corporation declares the low-carbon level x as y . Therefore, when $\Pi(i,i) \geq \Pi(i,j)$ for all $j \neq i$, it further implies:

$$\frac{\partial \Pi(i,j)}{\partial j} \Big|_{j=i} = 0 \quad (21)$$

And

$$\begin{aligned} \frac{\partial \Pi(x,y)}{\partial y} &= F'(y-x)[w_y + \beta_y e + p(y) - c(y,e) \\ &- \rho(y)v(y-x) - u(y-x)] + F(y-x)[p(y) - c'(y,e) \\ &- \rho'(y)v(y-x) - \rho(y)v'(y-x) - u'(y-x)] \end{aligned} \quad (22)$$

Substituting $(x,y) = (i,j)$, $i = j$, $F'(0) = 0^1$, we can derive Proposition 1:

$$\rho(j) = \frac{p'(j) - u'(0)}{v'(0)} \quad (23)$$

– **Proposition 1:** In the commitment-based mode, to satisfy the incentive compatibility condition between the investor and the corporation, the investor's verification capability should meet the condition

$$\rho(j) \geq \frac{p'(j) - u'(0)}{v'(0)}$$

Additionally, $\rho(y)$ also represents the threshold value for the incentive compatibility condition. Thus, $\rho'(y)$ indicates the incremental values of the commitment-based penalty u' and the outcome-based penalty v , reflecting the efficiency of these two penalty mechanisms. Specifically:

$$\rho'_u(y) = \frac{p'(y) - (u'(0) + \Delta u')}{v'(0)} - \frac{p'(y) - u'(0)}{v'(0)} = -\frac{\Delta u'}{v'(0)} \quad (24)$$

$$\rho'_v(y) = \frac{p'(y) - u'(0)}{v'(0) + \Delta v'} - \frac{p'(y) - u'(0)}{v'(0)} = -\frac{(p'(y) - u'(0)) \Delta v'}{v'(0) + \Delta v'} \quad (25)$$

Thus, only when $p'(y) > \frac{(v'(0) + \Delta v')}{v'(0) \Delta v'} \Delta u' + \Delta v'$, we have $\rho'_v(y) > \rho'_u(y)$, from this, we derive Lemma 1:

– **Lemma 1:** In the commitment-based mode, the greater the benefits the corporation derives from the project, the more impactful the commitment-based penalties become. Conversely, when the benefits accruing to the corporation are relatively modest; outcome-based penalties tend to be more effective.

In the analysis of overall societal benefit, a critical factor to consider is the investor's limited ability to accurately gauge the true extent of the corporation's low-carbon initiatives during the commitment phase. To address this, it becomes essential for the investor to review the related materials submitted by the corporation. The process of this verification incurs a cost for the investor, which is determined by the unit

verification cost f and scaled by the project size e . Therefore, the cost of verification fe becomes a significant component in the investor's calculations. As a result, the objective function for the investor, which aims to optimize the balance between verification costs and the societal benefits of the investment, can be expressed as follows:

$$\begin{aligned} \max \pi_h(i, e) &= e - r_i(e) - fe \\ \text{s. t. 1 } \pi_t(i, e) &\geq E[\pi_t(i, j)], \quad e = \operatorname{argmax} E[\pi_t(i, j)] \\ \text{s. t. 2 } \pi_t(i, e) &\geq 0 \end{aligned} \quad (26)$$

And

$$\frac{\partial E[\pi_t(i, j)]}{\partial e} = F(j-i)[\beta_j - b_i e - \rho(j)v'(j-i) - u'(j-i)] = 0 \quad (27)$$

So we have

$$\begin{cases} \beta_{jx}^* = 1 \\ b_{ix}^* = \frac{1 - \rho(j)v'(j-i) - u'(j-i)}{e} \end{cases} \quad (28)$$

Compared with Formula (13), we can derive Proposition 2:

$$b_{ix}^* < b_{ip}^*, i_x^* < i_p^* \quad (29)$$

– **Proposition 2:** In the commitment-based mode, corporations choose a lower level of carbon footprint reduction for the project compared to the outcome-based mode. The reason for the decrease in their level is that the commitment-based approach subjects corporations to additional assessments and potential penalties without offering corresponding rewards for exerting extra effort or fulfilling their commitments. Subsequently, we can derive the optimal solution for the investor's objective function under the incomplete information scenario for commitment-based mode:

$$\pi_{hx}^*(i, e) = \left(1 - \frac{A}{2} + \frac{\rho(j)v'(j-i)}{2} - f\right)e + p(i) \quad (30)$$

Where

$$w_{ix}^* = \frac{A - \rho(j)v'(j-i)}{2}e - p(i) \quad (31)$$

Compared with Formula (14), we can derive Proposition 3:

$$\pi_{hx}^*(i, e) - \pi_{hp}^*(i, e) = \left(\frac{\rho(j)v'(j-i)}{2} - f\right)ep(i) \quad (32)$$

¹ The proof of $F'(0) = 0$ can be found in Appendix A.

- **Proposition 3:** whether the investor's benefit (societal benefit) ultimately increases due to the commitment-based mode is influenced by the relationship between the commitment-based verification capability and the verification cost.

If $\frac{\rho(j)v'(j-i)}{2} > f$, then $\pi_{hx}^*(i,e) > \pi_{hp}^*(i,e)$, indicating that the commitment-based mechanism enhances societal benefits. Conversely, $\pi_{hx}^*(i,e) < \pi_{hp}^*(i,e)$, the commitment-based mechanism reduces societal benefits.

Considering the case where $\pi_{hx}^*(i,e) > \pi_{hp}^*(i,e)$ and combining with Proposition 2, it is observed that even though the corporation's effort level has decreased, the investor's benefit ultimately increases within this range. By integrating Formulas (15) and (31), we can derive Lemma 2:

- **Lemma 2:** When an investor adopts the commitment-based mode within a reasonable scope, even though the corporation chooses a lower level of carbon footprint reduction, investors can still amplify the societal benefits by avoiding unnecessary expenditures and improving investment utilization.

Conclusion

The investment decisions of green investors are increasingly influenced by corporate ESG commitments. However, theoretical research exploring the efficacy of this strategy is still relatively limited. This study integrates the characteristics of commitment-based investment and identifies equilibria under various scenarios through optimization. Conducting in-depth research on the changes in efficacy within this decision-making process is crucial to enhancing capital utilization efficiency among green investors, and this study may provide theoretical support for formulating investor policies.

This study, characterized by the constraint conditions of the commitment-based investment mode and influenced by current policies in related fields, constructs a comparative game model between outcome-based and commitment-based investment decision modes. By optimizing the objective function in the model, optimal solutions and their conditions of realization in various cases were derived. The study of the commitment-based mode revealed that: (1) To ensure the incentive compatibility mechanism between the investor and the corporation, the investor's verification capability must reach a certain threshold; (2) The greater the benefits derived by the corporation from the project, the more effective the penalty mechanism based on commitment review becomes. Further comparative research revealed that: (1) Under the commitment-based mode, corporations choose a lower level of carbon reduction than in the outcome-based mode; (2) Whether the commitment-based investment decision mode increases the investor's or societal benefits mainly depends on the relationship

between verification capability and verification costs; (3) Within a reasonable range, the commitment-based mode can enhance societal benefits by reducing wasteful expenditures and improving investment utilization.

Discussion

A key insight from our paper is that the commitment-based model is not universally applicable under all objective conditions, especially in cases with low transparency, where corporation commitments are often more about deceiving investors than genuinely demonstrating a stance on environmental protection. Under these circumstances, the 'learning by doing' strategy for investors is ineffective as well. Furthermore, even in principal-agent relationships that satisfy transparency requirements, it is not advisable to apply a commitment-based mode to all projects. This caution is due to the high verification costs and strategic responses by corporations, which can lead to a system of incentives and constraints riddled with meaningless consumption and inefficiency.

More broadly, this insight also reveals that the socio-economic landscape is a nonlinear and complex system. Rationally formulating policies for such a system and ensuring the achievement of desired outcomes is a task fraught with potential for unexpected effects, necessitating the consideration of numerous factors. Therefore, the formulation of any decision or policy measure should undergo thorough research and careful deliberation.

A current limitation of this paper, which also directs our future research, is that our study focuses solely on the conditions under which a single project can yield higher social benefits. In practical cases, investors frequently confront the challenge of allocating limited funds across multiple corporations [51]. Our paper has not addressed the aspect of 'scarcity', but the examination of fund allocation under conditions of resource constraints warrants further exploration.

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Conflict of Interest

The author declares no conflict of interest.

Appendix A

The proof of $F'(0) = 0$:

To investigate the value of $\frac{\partial F(x)}{\partial x} \Big|_{x=0}$, we must start with the steady-state situation of the corporation in the absence of influence from the investor:

Under the commitment-based framework, corporations encounter what can be termed a ‘pass-through assessment’. In this system, the reward structure does not offer additional incentives for surpassing the established performance standards. Moreover, the presence of a ratchet effect might even create adverse consequences for exceeding these standards. Consequently, the relationship between the actual output of the corporation and its utility takes the form of a piecewise function. In this function, if the output fails to meet the assessment threshold, the utility is 0. Conversely, if the output meets or surpasses this threshold, the utility is 1. This binary outcome reflects the all-or-nothing nature of the reward system in a commitment-based assessment. This is illustrated in Fig. A1 below:

Furthermore, consider the level of effort chosen by the corporation. Due to the uncertainty associated with effort, there is a probabilistic relationship between the level of effort and the actual output. Specifically, the output resulting from an effort level of ‘ α ’ by the corporation follows a quasi-normal distribution with a mean of ‘ α ’. This is illustrated in Fig. A2:

By synthesizing Fig. A1 and Fig. A2, and applying simplifications to the probability distribution: assuming the probability density beyond one standard deviation from the mean to be negligible, we can effectively ascertain the relationship between the level of effort exerted by the corporation and its expected utility. This simplification facilitates a more straightforward analysis, enabling a clearer understanding of how varying levels

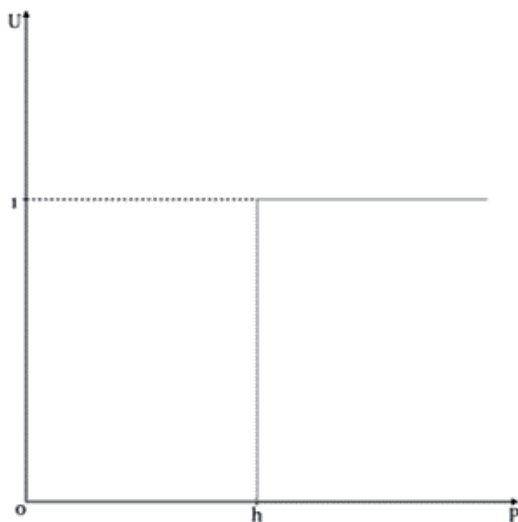


Fig. A1. Relationship between the corporation’s Output and Utility.

of corporation effort impact the anticipated utility in the context of our study’s framework. See Fig. A3:

By integrating the cost curve of the corporation’s level of effort, we can determine the relationship between the corporation’s effort cost and expected returns. See Fig. A4: From Fig. A4, we can further deduce that for the corporation, the relationship between the net benefit (difference between expected returns and costs) and the level of effort is shown in the following Fig. A5. It can be observed that the corporation has two evolutionarily stable strategy points: $e = 0$ and $e = h^*$. Disregarding $e = 0$, in a steady state, the corporation will choose, and only choose, the maximum value h^* of the net benefit function as the stable strategy.

“Since $F(j - i) = \frac{\pi_l(j)}{\pi_l(i)}$, and in the steady-state situation we have $i = h^*$, so $F'(0)$ represents the partial derivative $\frac{\partial U(e)}{\partial e} \Big|_{e=h^*} = 0 = F'(0)$ of the net benefit

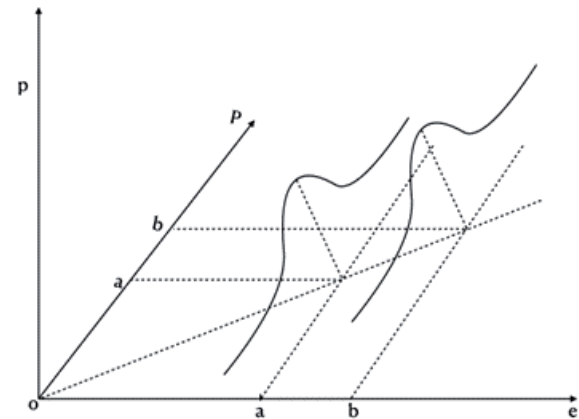


Fig. A2. Relationship between the corporation’s Level of Effort and Utility.

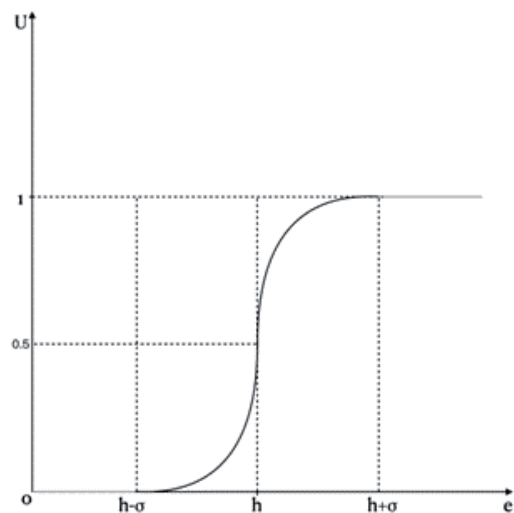


Fig. A3. Relationship between the corporation’s Level of Effort and Expected Utility.

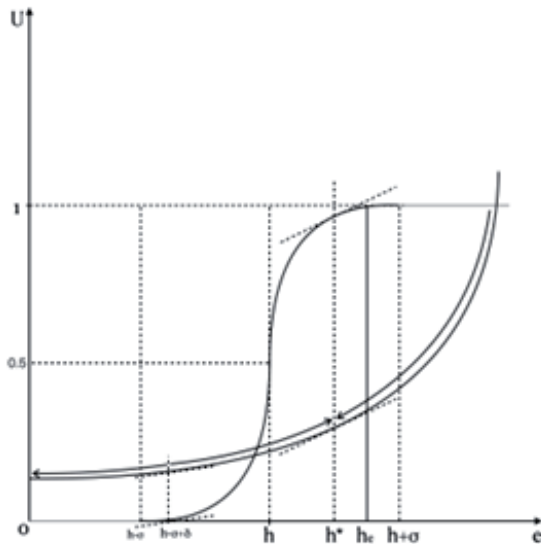


Fig. A4. Relationship between the corporation's Effort Cost and Expected Returns.

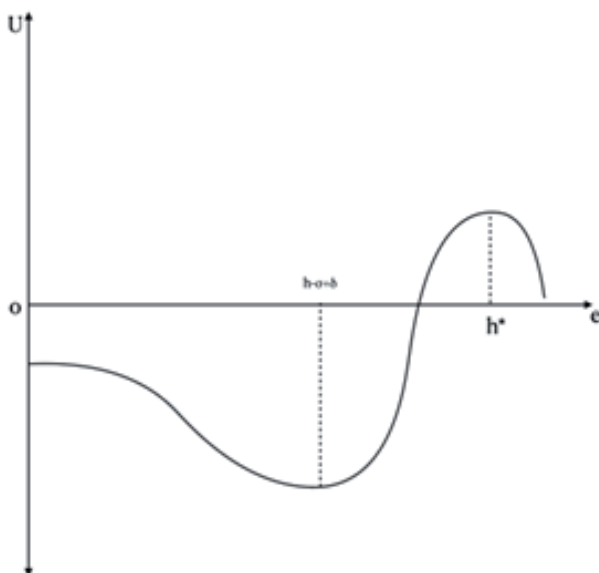


Fig. A5. Relationship between the corporation's Net Benefit and Level of Effort.

function at h^* as shown in Fig. A5. This proves the statement.

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