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Blockchain-based incentive mechanism for environmental, social, and governance disclosure: A principal-agent perspective

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Abstract

Environmental, social, and governance (ESG) disclosure has drawn much attention from listed companies, investors, and regulators. In response to the increasing demand of investors and regulators for non-financial information, listed companies have paid attention to publishing ESG reports consisting of environmental, social, and governance information. Listed companies are increasingly required to provide high-quality information that is clear and comparable. However, the lack of incentive to listed companies makes it hard to improve the quality of ESG disclosure, and the cost of ESG disclosure leads to the uncontrollable quality of ESG reports and may even manipulation by opportunistic behaviors. In this paper, we illustrate the moral hazard problem in ESG disclosure from the perspective of investors and listed companies, in which the effort level for listed companies to provide high-quality ESG report cannot be observed by investors. Then we propose a blockchain-based incentive mechanism for ESG disclosure from a principal-agent perspective to improve the information quality of ESG disclosure, where investors act as principal and listed companies act as agents. Token in blockchain technology is utilized as the rewards to improve the listed companies' reputation, thus increasing their chance of being promoted to investors for preferential investment opportunities in the blockchain platform. We then design the first-best (FB) and second-best (SB) optimal contracts based on classic principal-agent model to overcome the moral hazard problem. Extensive simulations are conducted to demonstrate the effectiveness and feasibility of the incentive mechanism.

KEYWORDS
blockchain, ESG disclosure, incentive mechanism, principal-agent model

1 | INTRODUCTION

Environmental, social, and governance (ESG) disclosure has drawn much attention from listed companies, investors, and regulators (Friede et al., 2015; Park & Jang, 2021; Pizzi et al., 2023). In response to increasing investor and regulator demand for non-financial information (Raimo et al., 2021), listed companies have paid attention to publishing ESG reports consisting of environmental information (e.g., Greenhouse Gas (GHG) emissions and water disposal, solution and renewable energy, among others), social information (e.g., employee makeup, human rights, equal opportunity to the workforce and product information), and governance information (e.g., political lobbying and anticorruption programs) (Amir & George, 2018; De Giuli et al., 2023). The overall ESG disclosure scenarios for listed companies typically include the report preparation stage, report generation stage, and report publication stage (Liu, Wu, et al., 2021). In the report preparation stage, listed companies collect the raw ESG information both from their internal and external stakeholders, and in the stage of report generation, the companies need to cooperate with professional service companies to produce a qualified ESG report (Liu, Wu, et al., 2021). In the report publication stage, listed companies publish the ESG reports to regulators and their homepages (HKEX, 2023). Through ESG disclosure, listed companies could reduce firm risk, promote long-term value creation (Albitar et al., 2020) and get more preferential investment opportunities (Mahoney et al., 2013), while external stakeholders could better monitor the management strategies of the firm's non-financial performance (Lokuwaduge & Heenetigala, 2017), decrease the information asymmetry between them and companies (Stubbs & Rogers, 2013), and guarantee several financial benefits (Raimo et al., 2021). Besides, recent studies have shown that enterprise performance is an important influencing factor in pursuing and improving ESG disclosure (Shi & Zhang, 2024; Vural-Yavaş, 2020).

Despite with the great benefits, ESG disclosure is still facing with critical incentive issues about improving information quality. Listed companies are increasingly required to provide high-quality information that is clear and comparable (Tettamanzi et al., 2022). For investors, they need the ESG information of companies with the following reasons. First, listed companies' ESG disclosure provides investors with value-related information to alleviate the information asymmetry that exists in investing in companies early in their life cycle (Dunne & McBrayer, 2019). Second, listed companies' ESG data is relevance to investment performance, investors prefer to incorporate ESG issues into their investment analysis process (Amir & George, 2018). In this study, we mainly concentrate on the incentive issues of listed companies, especially small and medium enterprises (SMEs). Although for large companies, the benefits of ESG disclosure often outweigh the costs, for SMEs, they enjoy less benefits, while the cost of capital increases significantly. ESG disclosure increases the chance that sensitive information containing clues to competitive advantage will be disclosed, enabling SMEs to be imitated by competitors (Gjergji et al., 2020). Esposito De Falco et al. (2021) helped understand how to incentivize SMEs to adopt enterprise innovation within ESG framework to improve their competitiveness. However, there is no incentive for private companies to improve their ESG disclosure quality in the absence of regulation (Chen & Xie, 2022), how to incentivize listed companies to provide high quality ESG report and overcome the information asymmetry between ESG stakeholders remain a problem.

Many incentive mechanisms for data sharing have been proposed in supply chain (Liu, Dan, et al., 2021; Wan & Qie, 2020; Wang, Qi, et al., 2021), IoV (Khalid et al., 2021; Wang, Ye, et al., 2021; Yin et al., 2020), crowdsensing (Yang et al., 2016; Zhan et al., 2018), and so forth. There are three mainstreams of the design of incentive mechanism: to motivate the participation of data owners in data sharing (Yang et al., 2016; Zhang et al., 2015); to establish a truthful environment for data owners and data demanders (Chen et al., 2020; Gan et al., 2017); to motivate the data owners to provide high-quality data (Wang et al., 2018; Yoo & Cheong, 2018). With the development of ESG disclosure, the quality assurance of ESG reports has increased (Tsang et al., 2023). Based on the research of Liu, Ge, and Wang (2023), the quality of enterprise ESG disclosure plays an important intermediary role in the effect of ESG rating on the financial risk of industrial companies. Moreover, Boesso et al. (2014) has proved better company performances are positively affected by better quality of voluntary ESG disclosure. However, how to improve the quality of voluntary ESG disclosure from the perspective of listed company is not mentioned. To address this issue, estimation of the data quality and design of the reward mechanism for contribution are commonly two issues crucial to design an effective incentive mechanism (Peng et al., 2018; Zhao et al., 2021). Besides, in the scenario of ESG disclosure, the characteristic of long-term value creation determines the incentive mechanism needs to satisfy the capacity of long-term quality awareness. Investors may have concerns about the credibility and usefulness of ESG reports (Tsang et al., 2023). However, a few researches have considered the long-term quality awareness in the design of incentive mechanism (Wang et al., 2018). They need to take full advantage of workers' historical information directly and predict their quality accurately, which is too complex in ESG disclosure because of diverse dimensional information. How to simplify the process of long-term quality awareness is the third issue remained to be solved in ESG disclosure.

To address the above challenges, this study mainly focuses the third stream, which relates to the quality of ESG reports. Due to the cost of collecting ESG information and expense of transforming it to ESG reports, the quality of ESG reports cannot be effectively controlled and may even be tampered by some uncontrollable factors. With these concerns, the purpose of this research is to incentivize listed companies to provide high-quality ESG reports by designing a token-based rewarding system from principal-agent perspective. We assume investors act as principal and listed companies act as agents. There exists a moral hazard problem in ESG disclosure that investors wish listed companies to provide high-quality ESG reports with high effort. However, listed companies have the incentive to decrease the standard and pay less effort to generate ESG reports to reduce cost. Apparently, moral hazard problem occurs when investors know nothing about how much effort the listed companies pay in generating ESG reports. Blockchain technology possesses the distributed, decentralized, and tamper-proof shared ledger characteristics, which could be beneficial to the transparent and secure data transmission (Shen et al., 2020). As the core constructs in blockchain, token is applicable for building the incentive mechanism. Tokens could be utilized as the rewards to motivate the users to share high-quality information (Harish et al., 2021). Besides, to overcome the information asymmetry in ESG disclosure, principal-agent model borrowed from economics is utilized as an appropriate framework to account for the invisibility of listed companies' effort (Nan, 2008). The optimal contract is designed for listed companies to motivate them to provide high-quality ESG reports. The higher-quality ESG reports the listed companies provide, the more token will be rewarded to earn better reputation with the benefit of higher chance to be promoted to investors for preferential investment opportunities.

Motivated by the importance of improving quality of ESG disclosure, this paper intends to answer the following research questions: (1) What is the optimal strategy for investors to design token-based contracts for listed companies and what is the optimal effort level for listed companies to pay in blockchain-based ESG disclosure? (2) What is the impact of incentive contract on listed companies and investors? (3) How robust are the incentive mechanism and the derived theoretical results?

The contributions of this paper can be summarized as follows. First, we have considered the type of listed companies based on the novel quality estimation mechanism of ESG reports and risk averse attitude towards token value. It can simplify the estimation process for investors and help them make investment decision. Second, we introduced blockchain technology into the incentive mechanism by utilizing tokens and considering the unit operation cost of using blockchain technology. The use of token helps investors and listed companies quantify the value of ESG disclosure and widen the application of token in designing incentive mechanism. Third, to overcome the moral hazard problem, we have proposed a self-revealing mechanism based on the framework of principal-agent theory. Both principal and agents will earn more utilities in incomplete information scenario. In specific, we have derived constraints, such as the incentive rationality and incentive compatible constraints, to guarantee the feasibility of incentive mechanism.

The rest of the paper is organized as follow. Section 2 provides a literature review of ESG disclosure, blockchain-based incentive mechanism for data sharing. The overall problem description is presented in Section 3. Section 4 describes the mechanism of proposed principal agent model. In Section 5, the simulation and analysis are presented to illustrate the effectiveness and feasibility. In Section 6, the research findings are further summarized to discuss the results listed in Section 5, followed by Section 7 to give the concluding remarks, theoretical implications and practical implications, limitations, and future research.

2 | LITERATURE REVIEW

2.1 | ESG disclosure

ESG disclosure is widely recognized as an important measure of corporate sustainability (Khan, 2022). Increasing researchers have studied ESG disclosure regarding the ESG extrinsic interaction effect (Broadstock et al., 2020; Khan, 2022; Zhang et al., 2020), quality of ESG disclosure (Ochi, 2018; Rabaya & Saleh, 2021) and driving factors of ESG disclosure (Amir & George, 2018; L'Abate, Vitolla, et al., 2023; Lokuwaduge & Heenetigala, 2017) based on a myriad theories (Chun et al., 2022), such as stakeholder theory (Aluchna et al., 2022; Vitolla, Raimo, Rubino, & Garzoni, 2019), legitimacy theory (Del Gesso & Lodhi, 2024; L'Abate, Vitolla, et al., 2023), and agency theory (Liu, Qian, et al., 2023).The mentioned theories have been widely applied on environmental-related practices. For example, L'Abate, Raimo, et al. (2023) explored the circular economy practices of companies from the perspective of stakeholders, and Liu, Qian, et al. (2023) used principal-agent theory in a macro perspective to explore the effect of ESG greenwashing on sustainable enterprise development, however, how to use the principal-agent model to overcome the information asymmetry in ESG disclosure still needs to be further studied explicitly.

Research on ESG extrinsic interaction effect mainly focuses on the relationship with enterprise performance. Khemir et al. (2019) conducted an experimental study to analyze and identify the effect of ESG information on investors' investment allocation decisions in Tunisian capital market. To fill the research gap of lacking comparative studies on ESG information disclosure practices remained by Khemir et al. (2019), Singhania and Saini (2021) performed a comparative analysis by conducting a comprehensive literature review on ESG regulatory frameworks for sample developed and developing countries. Park and Jang (2021) proposed a country specific ESG model for South Korea to identify the ESG factors' interaction effect on the process of investors making investment decisions. Therefore, the impact of ESG disclosure on enterprise performance is significant and the point of view supports our study of designing incentive mechanism for ESG disclosure.

Research on quality of ESG disclosure is located in quality estimation and investigation of influence factors. Michelon et al. (2015) investigated the quality of ESG disclosure in companies by using corporate social responsibility practices and their designed quality estimation approach to ESG disclosure consists of three complementary dimensions which inspires this study to design a novel concise quality estimation mechanism for ESG disclosure. Different with the above, Aluchna et al. (2022) chose to use descriptive statistics to present the overall characteristics of companies' ESG disclosure to investigate the institutional investor role in ESG disclosure. Arvidsson and Dumay (2021) focused on three trends in ESG reporting – quantity, quality and corporate ESG performance to evaluate ESG reporting quality. Ochi (2018) used contract theory as a frame of thought to build a ESG disclosure system which aims to contribute to a method of improving the quality of ESG disclosure. However, Ochi (2018) only attempted to design the method of incentivizing ESG disclosure theoretically, how to repaid the listed companies for high-quality ESG disclosure is not mentioned.

Research on driving factors of ESG disclosure is related to the incentive for ESG stakeholders to disclose ESG information. ESG concept was first introduced as a voluntary practice (Chun et al., 2022).

Przychodzen et al. (2016) found risk aversion, salary change and senior management approval/disapproval could be motivating factors for fund managers to incorporate ESG issues into investment decision making. Zhu and Zhang (2023) explored the local tournament incentives to influence the quality of ESG disclosure. Lee et al. (2023) investigated the incentive of ESG disclosure from managerial perspective. Although mandatory requirements have been issued in Hong Kong (HKEX, 2023), social responsibility is still full of humanitarianism. Listed companies have no incentive to improve their ecological environment and social goods (Chen & Xie, 2022). Relevant regulations and guiding solutions that incentivize listed companies to provide high-quality ESG reports are still absent to improve.

2.2 | Blockchain-based incentive mechanism for data sharing

Blockchain technology has achieved many cases in the financial, crowdsensing, and supply chain because of its distributed, decentralized, and tamper-proof shared ledger characteristics (Wu, Fu, et al., 2022; Xuan et al., 2020). For instance, in cross-border logistics there exists a risk of tampering because of the current information systems working in a centralized way. Blockchain technology is potential to promote information sharing through distributed networks and reduce costs by removing intermediaries (Wu, Li, et al., 2022). Besides, Liu et al. (2022) indicated that with the involvement of blockchain, changes will happen to the design of user incentive mechanism and their results show the positively effect on user's participation behavior.

There are three mainstreams of the design of incentive mechanism: to motivate the participation of data owners in data sharing (Yang et al., 2016; Zhang et al., 2015); to establish a multi-trust state for data owners and data demanders (Chen et al., 2020; Gan et al., 2017); to motivate the data owners to provide high-quality data (Wang et al., 2018; Yoo & Cheong, 2018). In the first stream, how to identify the reservation payoff for data owners is the critical issue. Liu et al. (2022) explored the influences of social capital and share capital on user participation behavior and enriched research on the incentive mechanism for user participation. In the second stream, how to overcome the information asymmetry in data sharing is the key to establish a multi-trust state. According to the research of Müller et al. (2020), trust as the relational capital was especially important for data sharing process. Dai et al. (2022) proposed a trust-driven incentive scheme by designing a trust evaluation scheme to guarantee the service quality in mobile crowd-sensing network. In the third stream, data quality evaluation and control are the key objective in designing such mechanism (Wang et al., 2018). Vitolla, Raimo, and Rubino (2019), Zhao et al. (2021) and Zhang et al. (2023) have contributed to designing quality-aware incentive mechanism. Vitolla, Raimo, and Rubino (2019) utilized agency theory approach to analyze the effect of board characteristics on integrated reporting quality. Zhao et al. (2021) considered reliability and deviation as data quality estimation factors to design their incentive mechanism for mobile crowdsensing. Zhang et al. (2023) focused on data quality control in data sharing process and utilized smart contract to realize security.

Economics theories like game theory, auction theory and contract theory have been applied to design such mechanisms. Xuan et al. (2020) proposed a data-sharing incentive model based on evolutionary game theory using blockchain with smart contracts to introduce the attributes of dynamic and timeliness in designing incentive mechanism. Gao et al. (2018) utilized auction theory to propose a data-quality incentive mechanism to select the minimum social cost bids. Chen et al. (2020) introduced a quality-driven auction-based incentive mechanism based on a consortium blockchain aiming to guarantee trust in both on-chain data and off-chain data, which helped to strengthen the research on building trust on off-chain data. Zhou et al. (2020) applied contract theory to develop a privacy-preserved, incentive-compatible, and spectrum-efficient framework based on blockchain. These mechanisms utilized blockchain technology as the medium in data sharing, which can motivate the participants to contribute to the sharing events. Blockchain technology could ensure the authenticity of on-chain data and once the data is uploaded to the blockchain, the data will never be changed factitiously. Meanwhile, considering the information asymmetry in ESG disclosure, where investors are hard to observe the fact quality of listed companies' ESG report and the process of generating ESG reports but listed companies know, contract theory is potential to resolve the moral hazard problem.

3 | PROBLEM DEFINITION AND MODEL PROPOSAL

In this section, we first analyze the value information flow in ESG disclosure. Then we define the design goals. Table 1 lists the main notations and descriptions used throughout the paper.

3.1 | Value chain model in ESG disclosure

Figure 1 illustrates the overall procedure of ESG disclosure, which is divided into three stages: report preparation, report generation, and report publication. In the stage of report preparation, it is mostly concerned with data collection, authentication, and processing. According to the checklist provided by the ESG reporting professional agency, listed companies collect relevant ESG data from Enterprises Information Systems. Then it comes to the stage of report generation, professional ESG consultants need to establish an ESG working group with senior management and staff with sufficient knowledge of ESG to make the use of provided ESG data to write ESG report. In the stage of report publication, listed companies once receive the ESG report from professional agencies and make a final check, they will publish the ESG report in regulator's system and their own homepages. Corresponding ESG stakeholders care about the report for their own interest, including investors, government, non-government organizations, credit rating agencies and industry associations. Specifically, the

TABLE 1 Notations used in this paper.

Notations		Description
A		The set of effort available to the listed companies to generate ESG reports
N		The set of listed companies
q		The quality level of the ESG reports
λ		The quality estimation coefficient of ESG report
t		Rewarded tokens to the listed companies
e		The unit value of blockchain token
θ_a		For listed companies (agents), the risk averse attitude parameter to token value
c_r		For listed companies, the unit cost of generating ESG reports
c_{bc}		The unit operation cost of using blockchain
m		The cost coefficient of the listed companies' effort to generate ESG reports
u_0		The reservation payoff for listed company to disclose ESG reports
u_p		For investors (principal), the use of blockchain creates a basic positive utility
u_a		For listed companies (agents), the use of blockchain creates a basic positive utility
U_{inv}		The utility of investor for one contract
U_{lc}		The utility of listed companies for one contract
Decision Variables	b	Bonus rate in the compensation contract. (Under the same quality of ESG report, listed companies will earn more tokens if the bonus rate is greater)
	t_0	The fixed payoff for the listed companies
	a	The efforts that listed companies used to generate ESG reports

investor can make a decision on investment by referring to these reports to select the enterprise who performs well in sustainability (Aluchna et al., 2022).

Figure 2 illustrates the value chain model in ESG disclosure which consists of blockchain-enabled ESG reporting platform (BESG),[1] listed companies, consultants, rating agencies, and investors. Figure 2 depicts the value information flow and monetary information flow in ESG disclosure. In the value chain model, the blue lines indicate the value information flow in ESG disclosure. First, listed companies collect ESG data from their Enterprise Information System based on ESG reporting guide (HKEX, 2023). Second, listed companies upload the relevant data to BESG platform as secure and tamper-resistant data asset for all the stakeholders in the consortium blockchain. Third, ESG consultants will get the reliable data from BESG platform. Fourth, ESG consultants generate ESG reports for listed companies by organizing professional working group. Fifth, once consultants finish the reports, they also need to upload ESG reports to BESG platform as a tamper-resistant way. Sixth, listed companies will approve the ESG reports after checking the quality of reports and then the reports will be identified as a public resource for ESG stakeholders. Seventh to ninth, rating agencies, one of ESG stakeholders, will download ESG reports from BESG platform to rate the quality level of ESG reports in industries and the rating results will be uploaded to BESG platform. Tenth, investors who care about ESG reports for their own interests can download reports and rating results from BESG platform, and finally to make their investment decisions. As for the red line, it means the monetary information flow in blockchain-based ESG disclosure. First, listed companies will be rewarded corresponding tokens for their submitted ESG reports in BESG platform. Listed companies could earn token rewards by providing high-quality ESG reports. A listed company has more token will have more chance to be promoted to investors to get preferable investment opportunities. Second, the payments provided by listed companies would be paid for consultants in BESG platform. Through analyzing the information in ESG reports, rating agencies will conduct ESG rating for the listed companies and upload the rating results to BESG so that investors could make their investment decisions for investment return according to ESG rating results. The third red line means investment return of investors.

We will simplify matters by assuming that there are only finitely many possible gross quality level for the investors, denoted by q, which is determined by the effort level a and λ. The details of λ will be described later. Let A be the set of actions a available to the listed companies to generate ESG reports. In the blockchain-enabled ESG reporting platform, the unit value of token after the disclosure period ends, denoted by e, a random variable which follows a density function of a systematic distribution with mean 1 and variance σ^2. We assume that the principal is risk neutral and the agents are risk averse. The risk averse attitude parameter towards token value for the listed companies is given by θ_a. When θ_p is zero, it means a higher variation of the value of token does not make any difference. When θ_a is negative, it means a higher variation of the value of token is unfavorable for listed companies. The principal will pay the agent according to the outcome of his action, that is, according to the ESG report's quality level.

Based on the value chain model, to improve the quality of ESG reports, listed companies could concentrate on four aspects to earn token rewards: transparency x_1, consistency x_2, timeliness x_3 and assurance x_4. The transparency of ESG reports is related to the disclosed ESG items, which is calculated by $x_1 = I_1/I_2$. I_1 is the number of disclosed ESG items while I_2 is the number of all required ESG items. The consistency is related to the raw data and ESG reports, which is calculated by $x_2 = D_1/D_2$. D_1 is the number of consistent data between raw data and ESG reports, D_2 is the number of raw data. The timeliness is related to the time attribute of ESG information. $x_3 = T_1 - T_2$. T_1 is the deadline of disclosing ESG reports, and T_2 is the time of last collecting data. For the assurance x_4, it is related to the obtained assurance from public company auditors or other assurance providers by listed companies. $x_4 = 0\, or\, 1$. When $x_4 = 0$, it means there is no assurance in the ESG reports. When $x_4 = 1$, it means there is at least one assurance in the ESG reports. Therefore, the listed companies' effort for generating ESG reports is expressed by a convex combination of each attribute x_i along with its corresponding

[1]BESG is described in the earlier literature (see e.g., Liu, Wu, et al., 2021).

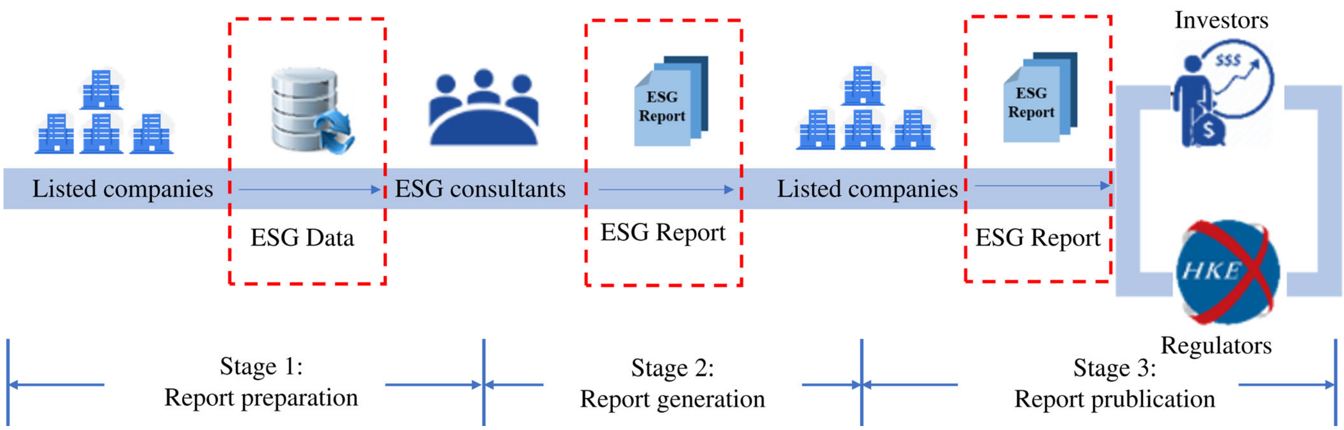

FIGURE 1 Overall procedure of ESG disclosure.

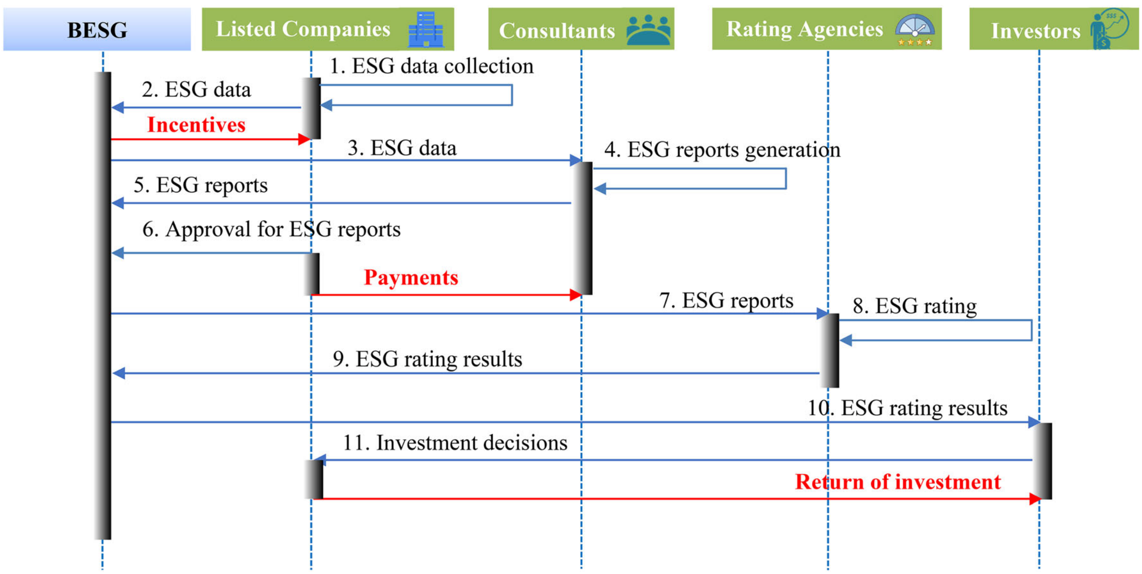

FIGURE 2 Value chain model in ESG disclosure.

importance or weight w_i (i.e., $\lambda = \sum_{i=1}^{4} w_i x_i$ where $\sum_{i}^{4} w_i = 1$ and $w_i \geq 0$ for all i). We have $a \geq 1$. The output function of listed companies is $q = \lambda \ln a$ (Chen et al., 2018). It is strictly increasing concave function, where $q(1) = 0, q'(a) > 0, and\, q''(a) < 0$ for all a. It means the quality of ESG reports will be improved with more efforts for listed companies. However, the improvement of quality will be decreased when taking more efforts to generate ESG reports. When $a = 1$, it means the listed company makes no effort to generate ESG reports.

The rewarded token t in the contract is determined by the quality of ESG reports q, which could be expressed as:

$$t = t_0 + bq = t_0 + b\lambda \ln a \tag{1}$$

where t_0 is a non-negative availability compensation for all the listed companies to disclose ESG reports, the slope b is the bonus rate and q is the listed companies' quality level.

3.2 | Model formulation

The profit function of investor and listed companies are derived in the following:

$$\tilde{\prod} investor = u_p + q - te - c_{bc} \tag{2}$$

$$\tilde{\prod} listed\ companies = te + u_a - c_r \tag{3}$$

Note that in (2) and (3), the investor receives the ESG reports from listed companies and hence q is not affected by the unit value of blockchain token e. As the token value is related to the reputation of listed companies, the unit blockchain cost c_{bc} and unit cost of generating ESG reports c_r are not scaled with e. For the rewarded token t, it is scaled with e. As e is a random variable, all the profit functions are random. Based on the economic principle, the profit of investor and listed companies are their revenue minus cost. The revenue of investors in this study are the sum of positive utility created by using blockchain u_p and q while their cost is the paid token value te and unit cost of using blockchain c_{bc}. The revenue for listed companies is the sum of the earned token value te and positive utility created by using blockchain u_a, and the cost is the fees to generate ESG reports such as the consultant fees and data collection fees.

With (2) and (3), we can get the expected profit functions as well as the standard deviation of profit functions (SDP) (Choi et al., 2020) as follows.

$$\overline{\prod} inv = E\left(\tilde{\prod} inv\right) = u_p + q - t - c_{bc} \tag{4}$$

$$\overline{\prod} lc = E\left(\tilde{\prod} lc\right) = t + u_a - c_r \tag{5}$$

$$\overset{\Lambda}{\prod} lc = \sqrt{V\left(\tilde{\prod} lc\right)} = t\sigma \tag{6}$$

Followed by Choi (2020), we employ the mean-risk theory in which the "mean" is represented by the expected profit and "risk" is modeled by SDP. As the investor is risk neutral, the risk parameter is 0. The objective functions of risk sensitive ESG stakeholders are hence given below:

$$U_{inv} = -\overline{\prod} inv + \theta_{inv} \overset{\Lambda}{\prod} inv = u_p + q - t - c_{bc} \tag{7}$$

$$U_{lc} = -\overline{\prod} lc + \theta_a \overset{\Lambda}{\prod} lc = t + u_a - c_r + \theta_a t\sigma \tag{8}$$

We assume the $c_r(a) = \frac{m}{2}a^2$, $(m > 0)$ is the cost of the listed companies' action to generate ESG reports which is related to the fees paid for the consultants and cost of collecting raw data. The cost function has the property of $c_r{}' > 0 \, and \, c_r{}'' < 0$.

The incentive mechanism is designed to satisfy the following two economic properties.

1. Individual Rationality (IR): A mechanism is individually rational if the utility is non-negative for each listed company.
2. Incentive Compatible (IC): A mechanism is designed compatible for each quality type of information if the listed companies prefer to choose the high-quality level.

The investor's problem is to design an incentive contract package, (t,q), that induce the listed companies to provide high-quality ESG reports with appropriate amount of effort. However, the contract is associated with a moral hazard problem in which investors cannot choose the listed companies' action a. Meanwhile, the listed companies want to choose the optimal contract package on the incentive scheme that can maximize their utilities.

The incentive mechanism for ESG disclosure could be converted to find the optimal solution of following problem.

$$\max U_{inv} = \max u_p + q - t - c_{bc} \tag{9}$$

s.t.

$$t + u_a - c_r + \theta_a t\sigma \geq u_0 \tag{IR}$$

$$a \in \underset{a \in A}{argmax} t + u_a - c_r + \theta_a t\sigma \tag{IC}$$

4 | INCENTIVE MECHANISM FOR ESG DISCLOSURE

4.1 | Principal agent model for ESG disclosure

ESG stakeholders are heterogeneous with different preference towards ESG disclosure, but have the same aim in disclosing ESG reports which is maximizing their own profits. The moral hazard problem in ESG disclosure lies in that BESG can only control the quality of on-chain data, however it is not aware of the fact quality of data provided by the listed companies while the companies themselves know. Considering there exists information asymmetry between investors and listed companies, we propose a principal-agent model to overcome the information asymmetry where investor as the principal, offers compensation contract package (t,q) to the listed companies who play the role of agent. t is the reward token that the principal needs to pay for the agents who provide the required fact-level data q. In the incentive mechanism, principal provides agents with incentive tokens to motivate agents to provide high quality-level ESG report in BESG platform. We have considered the two economic properties: individual rationality and incentive compatible. First of all, each agent has their own basic utility u_0 limit to disclose ESG reports in BESG platform, which means the incentive mechanism must provide more positive reward than u_0 to attract more agents to join. That is called incentive rationality, thanks to which the incentive mechanism can work. Second, intuitively, the greater q should be rewarded more and vice versa, which is called incentive compatible. Due to the property incentive compatible, the mechanism can motivate agents have more willingness to provide high quality-level ESG reports. The principal-agent model for ESG disclosure is depicted as Figure 3.

The incentive mechanism from the perspective of principal-agent can be described as follows: First, investors offer a compensation contract package (t,q) to agents. Second, the agents decide whether to accept or reject the contract package. Third, if the agents accept, they need to generate ESG reports with the cost of c_r. Fourth, the agents need to provide the ESG reports to the BESG with the required quality level. Fifth, the BESG will review the uploaded ESG reports and finally, the token incentives will be rewarded to the agents according to the selected contract. The listed companies with more token will be considered as more reputational in ESG disclosure which means the quality of ESG reports is

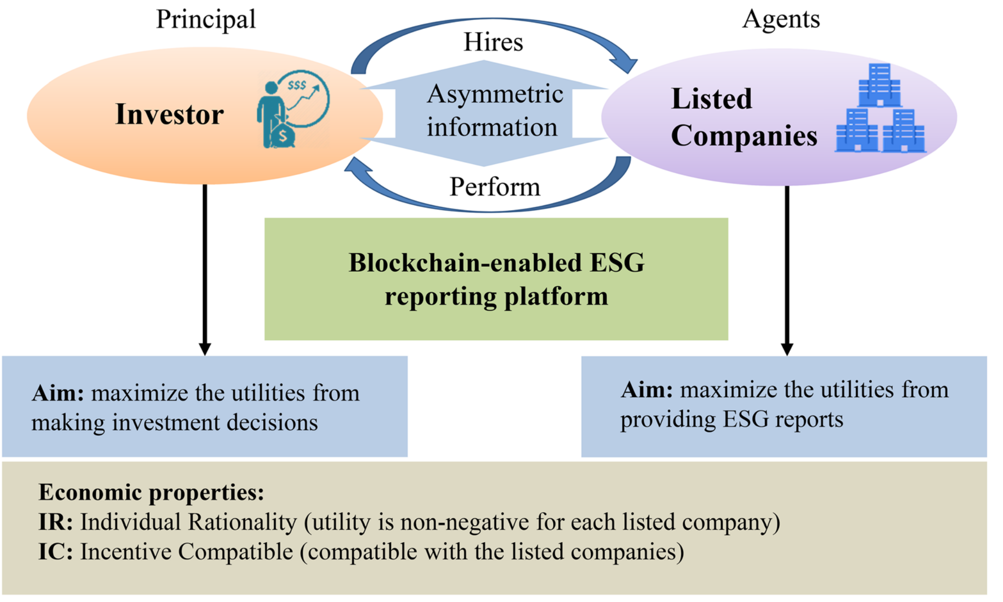

FIGURE 3 Principal-agent model for blockchain-based ESG disclosure.

higher and have more opportunities to earn the investment from investors.[2]

4.2 | Optimal contract design

Based on the principal agent model proposed in Section 4.1, investors need to design the optimal contract for maximizing their profit. We consider two scenarios in optimal contract design: complete information and incomplete information.

4.2.1 | Complete information scenario

In the complete information scenario, the investor is ideally aware of all listed companies' report quality. Given that, the investor only has to deliver one acceptable contract to each listed company. We consider it as a benchmark case and take the optimal investor's expected profit with complete information as the up-bound for the performance of incentive mechanism. Based on this scenario, we assume that agents are risk neutral (i.e., $\theta_a = 0$) and the constraint of IC is redundant. Besides, we make the assumption that the ESG data uploaded to the blockchain is correct to simplify the solution procedure.

The principal's problem can be described as follows.

$$\max U_{inv} = \max u_p + q - t - c_{bc} \tag{10}$$

s.t.

$$t + u_a - c_r \geq u_0(\mathrm{IR})$$

[2]The token flow process could be described as follows: The investors need to buy tokens from the BESG platform by currency. When investors have tokens in their account, they could publish the contract for listed companies in the BESG by setting different tokens for specific quality level of ESG reports. Listed companies could be promoted to investors by BESG to earn more possible investment.

According to (1) and $c_r(a) = \frac{m}{2}a^2$, the problem could be converted as follow:

$$\max U_{inv} = \max u_p - t_0 - c_{bc} + \lambda \ln a - b\lambda \ln a \tag{11}$$

s.t.

$$t_0 + b\lambda \ln a - \frac{1}{2}ma^2 + u_a \geq u_0(IR)$$

For the listed companies, they want to maximize their benefits, that is

$$\max U_{lc} = \max t_0 + b\lambda \ln a - \frac{1}{2}ma^2 + u_a \tag{12}$$

According to the first-order optimal condition, the optimal effort level of listed companies with given t_0 and b is:

$$a_{FB}^{*} = \sqrt{\frac{b\lambda}{m}} \tag{13}$$

In the scenario of complete information, the investors only need to pay the basic utility of u_0. Then we have:

$$t_0 + b\lambda \ln a - \frac{1}{2}ma^2 + u_a = u_0 \tag{14}$$

According to solve the first-order condition with respect to b based on (11) and (14), the optimal bonus rate is $b = 1$. According to (13), we have:

$$t_0 = u_0 - u_a + \frac{\lambda}{2}\left(1 - \ln\frac{\lambda}{m}\right) \tag{15}$$

To make sure $a>1$, we could have $\lambda>m$. It means the listed companies need to reduce their cost as much as possible, or they will not have the desire to disclose high-quality ESG reports.

Lemma 4.1. *Under complete information scenario, the optimal decisions for principal and agents are:*

$$a_{FB}^{*}=\sqrt{\frac{b\lambda}{m}},b=1,t_0=u_0-u_a+\frac{\lambda}{2}\left(1-ln\frac{\lambda}{m}\right)$$

Proof of Lemma 4.1: All proofs are placed in Appendix A.

4.2.2 | Incomplete information scenario

In incomplete information scenario, the investor does not know the actual actions paid for generating ESG reports. Instead, it only has the general knowledge of listed companies' ESG reports' quality. Due to the moral hazard problem, the investor's expected profit is considered to have some loss compared with the benchmark. We assume listed companies are risk averse here. Based on the work of Wang and Shao (2012), there exists risk cost for listed companies, which is expressed as $\frac{1}{2}\theta_a b^2\sigma^2$. Based on principal-agent theory, the incentive model of risk-averse listed companies can be described as follows.

$$\max U_{inv}=\max u_p+q-t-c_{bc} \tag{16}$$

s.t.

$$t+u_a-c_r+\theta_a t\sigma-\frac{1}{2}\theta_a b^2\sigma^2\geq u_0 \tag{IR}$$

$$a\in \underset{a\in A}{argmax}\, t+u_a-c_r+\theta_a t\sigma-\frac{1}{2}\theta_a b^2\sigma^2 \tag{IC}$$

According to (1) and $c_r(a)=\frac{m}{2}a^2$, the problem could be converted as follows.

$$\max U_{inv}=\max u_p-t_0-c_{bc}+\lambda lna-b\lambda lna \tag{17}$$

s.t.

$$t_0+b\lambda lna-\frac{1}{2}ma^2+u_a+\theta_a\sigma(t_0+b\lambda lna)-\frac{1}{2}\theta_a b^2\sigma^2\geq u_0 \tag{IR}$$

$$a\in \underset{a\in A}{argmax}\, t+u_a-c_r+\theta_a t\sigma-\frac{1}{2}\theta_a b^2\sigma^2 \tag{IC}$$

For the listed companies, their problem is listed as follows.

$$\max t_0+b\lambda lna-\frac{1}{2}ma^2+u_a+\theta_a\sigma(t_0+b\lambda lna)-\frac{1}{2}\theta_a b^2\sigma^2 \tag{18}$$

According to solve the first-order condition with respect to a be zero, we have the second-best action as:

$$a^{*}{}_{SB}=\sqrt{\frac{b\lambda(1+\theta_a\sigma)}{m}} \tag{19}$$

The investor maximizes their profit by providing the basic utility of listed company, which is expressed as:

$$t_0+b\lambda lna-\frac{1}{2}ma^2+u_a+\theta_a\sigma(t_0+b\lambda lna)-\frac{1}{2}\theta_a b^2\sigma^2=u_0 \tag{20}$$

According to (17), (19) and (20), we could have the optimal b according to solve the first-order condition with respect to b be zero.

$$b^{*}=\frac{-\lambda-\theta_a\sigma\lambda\pm\sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda+\theta_a\sigma\lambda+8\theta_a\sigma^2}}{4\theta_a\sigma^2} \tag{21}$$

Due to the constraint of $b>0$, we could have the optimal b as follow.

$$b^{*}=\frac{-\lambda-\theta_a\sigma\lambda+\sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda+\theta_a\sigma\lambda+8\theta_a\sigma^2}}{4\theta_a\sigma^2} \tag{22}$$

We further obtain the optimal effort level for listed companies, optimal fixed compensation, which are expressed as:

$$a^{*}{}_{SB}=\sqrt{\frac{-\lambda-\theta_a\sigma\lambda+\sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda+\theta_a\sigma\lambda+8\theta_a\sigma^2}}{4\theta_a\sigma^2}}\sqrt{\frac{\lambda(1+\theta_a\sigma)}{m}} \tag{23}$$

Lemma 4.2. *Under the incomplete information scenario, the optimal decisions for principal and agents are:*

$$b^{*}=\frac{-\lambda-\theta_a\sigma\lambda+\sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda+\theta_a\sigma\lambda+8\theta_a\sigma^2}}{4\theta_a\sigma^2},$$

$$a^{*}{}_{SB}=\sqrt{\frac{-\lambda-\theta_a\sigma\lambda+\sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda+\theta_a\sigma\lambda+8\theta_a\sigma^2}}{4\theta_a\sigma^2}}\sqrt{\frac{\lambda(1+\theta_a\sigma)}{m}},$$

$$t_0{}^{*}=\frac{-b\lambda lna+\frac{1}{2}ma^2-u_a-\sigma b\lambda lna+\frac{1}{2}\theta_a b^2\sigma^2+u_0}{1+\theta_a\sigma}$$

Proof of Lemma 4.2: All proofs are placed in Appendix A.

5 | NUMERICAL SIMULATIONS AND ANALYSIS

In this section, we conduct numerical simulations to evaluate the performance of the proposed blockchain-based incentive mechanism for motivating listed companies to disclose high-quality ESG reports. In specific, we will first observe the feasibility of the contracts obtained by the principal-agent model. Then by observing individual listed companies' ESG reports belongs to different quality under both complete and incomplete information scenarios, we evaluate the overall system performance under different network conditions. Finally, we can

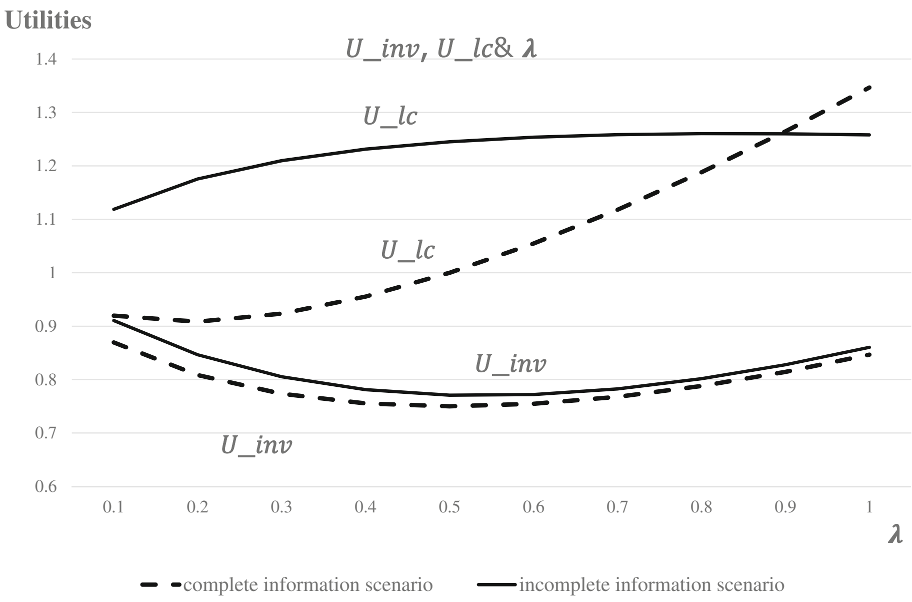

FIGURE 4 System performance of two information scenarios in different ESG reports' quality.

examine how quality estimation coefficient of ESG report, the absolute risk averse attitude parameter to token value, cost coefficient of the listed companies' effort to generate ESG reports and standard deviation of unit value of blockchain token affect bonus rate given by investors and effort level paid by listed companies.

Figure 4 shows the utilities of listed companies and investors in complete information scenario and incomplete information scenario. The utilities of investors and listed companies in complete information scenario are calculated based on Equations (11) and (12) and Lemma 4.1 while the incomplete information scenario is calculated through Equations (17) and (18) and Lemma 4.2. The sum of basic positive utility for investor and listed companies to use blockchain minus the basic utility of listed companies to accept the contract is set as 0.5 ($u_p + u_a - u_0 = 0.5$), the unit cost of using blockchain is set as 0.1 ($c_{bc} = 0.1$). The cost coefficient of the listed companies' effort to generate ESG reports is set as 0.5 ($m = 0.5$). The value range of quality estimation coefficient of ESG report λ is 0 to 1 at 0.1 interval.

We could see according to our incentive mechanism the investors and listed companies could increase their utilities by overcoming information asymmetry. For investors, we can see that their utility has a short decrease when the ESG reports' quality is higher, but then their utility will have a stable increase with higher ESG reports' quality. This is because ESG reports with low level of quality ($\lambda < 0.6$) have very limit valuable and dependable information for investors. In the poor level of quality ($\lambda < 0.6$), the ESG information may not help investor make reasonable investment decisions, and even mislead the investors to do damage to their interests. To be general, the feasibility of the incentive mechanism is verified effectively because the utilities of listed companies and investors are increased as the quality level improves by the rewarding mechanism whether in the complete information scenario or incomplete information scenario. Besides, according to the token-based incentive mechanism, the information asymmetry in ESG disclosure is improved with the evidence that investors and listed companies have more utilities in the incomplete information scenario significantly.

Through numerical simulations, we verify the interaction between bonus rate b, effort level a and, quality estimation coefficient of ESG report λ, the absolute risk averse attitude parameter to token value θ_a, cost coefficient of the listed companies' effort to generate ESG reports m and standard deviation of unit value of blockchain token σ based on Lemma 4.2. We use the concise way θ to substitute for θ_a in Figure 5. In the analysis between λ and b, we make three conditions for the parameters θ_a and σ ($\theta_a = 0.5$, $\sigma = 0.5$;$\theta_a = 0.1$, $\sigma = 0.5$;$\theta_a = 0.5$, $\sigma = 0.1$) to better analyze the relationship from different perspectives. In the first condition, $\theta_a = 0.5$, $\sigma = 0.5$ means the listed companies whose absolute risk averse attitude parameter to token value is 0.5 and standard deviation of unit value of blockchain token is 0.5. In the second condition, $\theta_a = 0.1$, $\sigma = 0.5$ means the different type of listed companies whose absolute risk averse attitude parameter to token value is 0.1 and standard deviation of unit value of blockchain token is 0.5. In the third condition, $\theta_a = 0.5$, $\sigma = 0.1$ means the same listed companies as the first condition disclose ESG information in different environment whose absolute risk averse attitude parameter to token value is 0.5 and standard deviation of unit value of blockchain token is 0.1. Similarly, we make three conditions ($\lambda = 0.5, \sigma = 0.5$; $\lambda = 0.5, \sigma = 0.1$; $\lambda = 0.1, \sigma = 0.5$) for the parameters λ and σ in the analysis between θ_a and b, and three conditions ($\lambda = 0.5, \theta = 0.5$; $\lambda = 0.5, \theta = 0.1$; $\lambda = 0.1, \theta = 0.5$) for the parameters λ and θ_a in the analysis between σ and b. Figure 5 illustrates the relationship between b with λ, θ_a, and σ.

From Figure 5, we can find out the following results:

- When analyzing the relationship between the quality level of ESG reports and bonus rate, the quality level of ESG reports affects bonus rate given by the investor positively or vice versa, implying

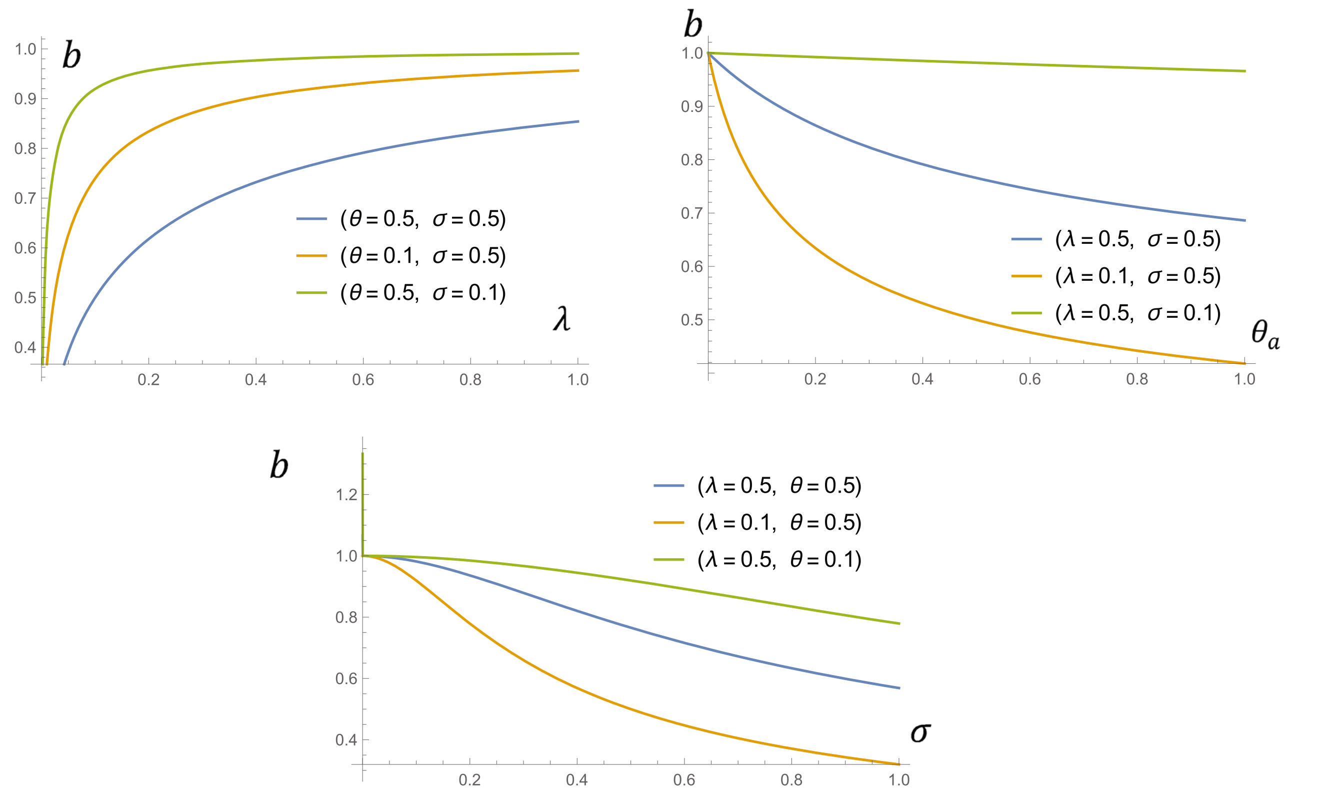

FIGURE 5 Relationship between bonus rate b and quality estimation coefficient λ, absolute risk averse attitude parameter to token value θ_a, and standard deviation of unit value of blockchain token σ.

the bonus rate will increase as quality level is improved. Based on the law of diminishing marginal utility, the optimal quality level that listed companies want to produce in the third condition ($\theta_a = 0.5, \sigma = 0.1$) is lowest while the optimal bonus rate is the best. However, investors have predicted this situation and will consider the first condition ($\theta_a = 0.5, \sigma = 0.5$). Meanwhile, listed companies can also predicted this decision from investors. To achieve the all-win situation, the second condition ($\theta_a = 0.1, \sigma = 0.5$) may be accepted by both investors and listed companies.

- When analyzing the relationship between bonus rate and the risk averse attitude parameter to token value, the risk averse attitude affects bonus rate given by the investor negatively, implying if listed companies can accept more risk and being slightly risk-seeking can earn greater bonus rate and thus more expected benefits. Besides, we find that the optimal bonus rate for both investors and listed companies to achieve all-win situation in the given three conditions is in the first condition ($\lambda = 0.5, \sigma = 0.5$). Accordingly, listed companies should provide higher quality-level ESG reports when facing the same external environment.
- When analyzing the relationship between bonus rate and the standard deviation of unit value of blockchain token, bonus rate given by the investor is negatively related to the standard deviation of unit value of blockchain token, which reason is that listed companies take more risk in ESG disclosure, and they will have less confidence in the token incentives. Meanwhile, investors will have less confidence to earn investment return if the risks of token value increase. We find that the optimal bonus rate for listed companies and investors is in the first condition ($\lambda = 0.5, \theta = 0.5$). Similarly, listed companies should provide higher quality-level ESG reports when their attitude to risk is fixed.

In the analysis of effort level a and quality estimation coefficient of ESG report λ, the absolute risk averse attitude parameter to token value θ_a, cost coefficient of the listed companies' effort to generate ESG reports m and standard deviation of unit value of blockchain token σ, we consider the four conditions for each analysis in Figure 6. For example, in the analysis of a and λ, we set four conditions: $\theta = 0.5, \sigma = 0.5, m = 0.5; \theta = 0.5, \sigma = 2, m = 0.5; \theta = 0.5, \sigma = 0.5, m = 4; \theta = 2, \sigma = 0.5, m = 0.5$. In the first condition $\theta = 0.5, \sigma = 0.5, m = 0.5$, it is set as the benchmark to compare with each other three conditions and it means listed companies whose risk averse attitude is 0.5 and unit cost of generating ESG reports is 0.5 disclose ESG information in the environment of $\sigma = 0.5$. Similarly, we set four conditions for the other three analysis. In the analysis of a and θ_a, we set four conditions: $\lambda = 0.5, \sigma = 0.5, m = 0.5; \lambda = 0.5, \sigma = 2, m = 0.5; \lambda = 0.5, \sigma = 0.5, m = 4; \lambda = 1, \sigma = 0.5, m = 0.5$. In the analysis of a and σ, we set four conditions: $\lambda = 0.5, \theta = 0.5, m = 0.5; \lambda = 0.5, \theta = 2, m = 0.5; \lambda = 0.5, \theta = 0.5, m = 4; \lambda = 1, \theta = 0.5, m = 0.5$. In the analysis of a and m, we set four conditions: $\lambda = 0.5, \theta = 0.5, \sigma = 0.5; \lambda = 0.5, \theta = 2, \sigma = 0.5; \lambda =$

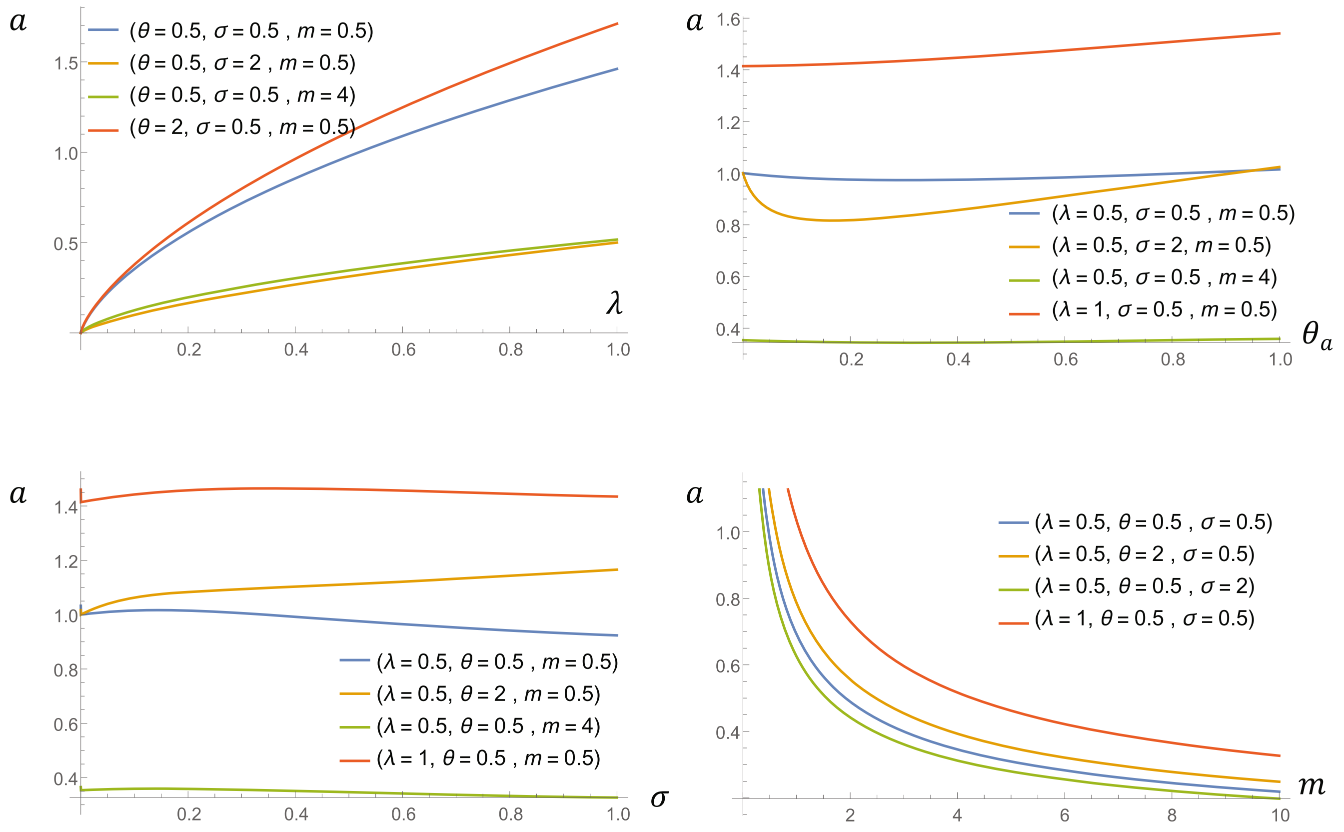

FIGURE 6 Relationship between effort level a and quality estimation coefficient λ, risk averse attitude parameter to token value θ_a, standard deviation of unit value of blockchain token σ, and cost coefficient of the listed companies' effort to generate ESG reports m.

$0.5, \theta = 0.5,\ \sigma = 2; \lambda = 1, \theta = 0.5,\ \sigma = 0.5$. Figure 6 illustrates the relationship between a with λ, θ_a, m and σ.

From Figure 6, we can find out the following results:

- The effort listed companies need to pay in ESG disclosure is positively related to the quality estimation coefficient. In our incentive mechanism, investors could see how much effort listed companies pay by observing which contract listed companies select which helps alleviate the information asymmetry in ESG disclosure.
- The listed companies' risk averse attitude parameter to token value has slight effect on their effort paid in ESG disclosure. Although in the second condition ($\lambda = 0.5, \sigma = 2, m = 0.5$), the listed companies prefer to pay less effort when their risk averse attitude is low and then the effort will become more as their attitude strengthens. This is because the external environment varies harder, and listed companies need to change their business decisions if they want to seek more risks or avoid more risks.
- The external environment affects listed companies' effort paid in ESG disclosure slightly. Specifically, with the external environment varies harder, listed companies which prefer more risks will have more willingness to pay more effort in ESG disclosure. However, this effect is too slight to consider it as the basis of major business strategy decision.
- The cost coefficient is obviously related to the effort level negatively, which reason is that the higher cost of listed companies will increase the burden of ESG disclosure. However, the slope of a/m is decreasing which implies when a larger cost will have less influence to the effort level.

6 | DISCUSSION

In our analysis above, the study has produced significant findings to help investors motivated listed companies to disclose high quality-level ESG reports and decrease the information asymmetry by observing the effort level listed companies paid in ESG disclosure. Answering the research questions presented in Section 1, we generate many important and novel findings. First, this study contributes to making optimal strategies for listed companies and investors under blockchain technology. The blockchain-based incentive mechanism drives token circulation and value generation in ESG disclosure for ESG stakeholders. Tokens issued by the blockchain incentive mechanism are utilized as a reputational symbol and represent the reputational benefits for listed companies. Recent literature has focused on the use of tokenization incentive (Choi, 2020, 2022; Harish et al., 2023). We developed the reputational value of crypto tokens following the research of Harish et al. (2023) which built a token value ecosystem for crowdsensing in ESG disclosure. Our results show higher quality level of ESG reports helps both listed companies and investors to achieve higher utilities in a certain range (quality level is greater than 0.6), which satisfy the economic properties of individual rationality and incentive compatible.

Second, we have interestingly uncovered the impact of incentive contract on listed companies and investors. In the principal-agent model for ESG disclosure, we find the risk averse attitude affects bonus rate given by the investor negatively, which is different from the findings of Choi (2020) in supply chain management. Listed companies' risk attitude towards to token value is an important identification factor for investors to make their investment decisions. However, the basic positive utility generated by blockchain for investors and listed companies do not play any role in the incentive mechanism. This finding helps investors to identify the impact of incentive contract on listed companies. As for listed companies, they could make corresponding strategy based on their own risk averse attitude. Besides, the quality level of ESG reports has proved to be high to achieve the win-win state for both listed companies and investors. Specifically, investors prefer to set the requirements of ESG reports' quality level as at least 0.6 and listed companies would prefer to pay corresponding effort level to generate ESG reports of quality level 0.6 or above in return to achieve a win-win state. External environment of token value also plays a role in designing the incentive contract. Choi (2020) considered the external environment variation of token value but he mainly focused on investigating impacts of agents' risk attitudes towards token and rarely further analyzed the impact of external environment on agents' risk attitudes. Although we didn't investigate the impact of external environment on risk averse attitude, we believe there may exists some relevance between them. The evidence is that in our sample of Figure 5 ($b-\sigma$), when facing the same external environment and quality level requirement, listed companies which prefer to seek risk will earn a higher bonus rate contract.

Third, we have proved the robust state of the derived theoretical results. We compared the system performance of complete and incomplete information scenarios in different ESG reports' quality and set three conditions for comparatively analyzing the relationship between bonus rate and impact factors and four conditions for comparatively analyzing the relationship between effort level and impact factors. The overall results show that the main finding remains valid when vary the impact factors except for the external environment of token value. If the external environment of token value is not stable, the listed companies prefer to pay less effort when their risk averse attitude is low and then the effort will become more as their attitude strengthens. This is because the external environment varies harder, and listed companies need to change their business decisions if they want to seek more risks or avoid more risks. However, the listed companies' risk averse attitude to token value has slight effect on their effort paid in ESG disclosure and effect of external environment is also too slight to consider it as the basis of major business strategy decision.

7 | CONCLUSION

7.1 | Concluding remarks

Listed companies especially SMEs lack incentives to improve their ecological environment and social goods (Chen & Xie, 2022) and the result is that the absent regulations affect the ESG report greenwashing of enterprises (Liu, Qian, et al., 2023). In this paper, we have proposed a blockchain-based incentive mechanism from principal-agent perspective for addressing the problem of motivating listed companies to disclose high-quality ESG reports. We depict and formulate the value generation process in ESG disclosure. We then solve the principal-agent game and find the first-best optimal solutions in complete information scenario and second-best optimal solutions in incomplete information scenario for investors and listed companies to make their optimal strategies. We analytically investigate the impact of quality estimation coefficient, risk averse attitude to token value, and standard deviation of unit value of blockchain token on bonus rate decisions from investors and effort level from listed companies. From the principal-agent perspective, investors as the principal will receive their high-quality ESG reports while listed companies could get more opportunities to be promoted to listed companies to earn investment. The system performance and major insights have proved to be valid through various comparative analysis.

7.2 | Theoretical implications

The theoretical contributions of this study are three-fold. First, this is one of the early studies to discuss the incentive framework and moral problem in ESG disclosure. In the absent regulation, listed companies have no incentive to improve their ESG disclosure quality (Chen & Xie, 2022) and information asymmetry has been observed between cost and benefits of corporates' ESG disclosure (Chen & Xie, 2022). Considering this background, this study is a novel attempt to build the incentive framework in ESG disclosure. Second, this study extends the application field of agency theory in ESG disclosure and examines the performance of principal-agent model in designing incentive mechanism for ESG disclosure. The design of setting investors as principal and listed companies as agents in blockchain platform provides a novel perspective for ESG disclosure studies and this may enlighten the research on exploring relationship between investors and listed companies in ESG disclosure. Third, the application of blockchain technology on ESG disclosure is one of the early studies to develop the credibility assurance approach to ESG disclosure. Blockchain technology contributes to establishing a transparent environment for each ESG stakeholders and the use of token value is further developed based on the work of Harish et al. (2023) and Choi (2020), the reputational value of token and the risk attitude towards token are combined in this study to design the incentive mechanism, which provides reference value for the development of token value in blockchain.

7.3 | Practical implications

The findings of this study help listed companies, investors and other ESG stakeholders understand the value generation in blockchain-based ESG disclosure and the effect of transparent disclosure environment on business and societal development, which satisfy the requirement of recent ESG Reporting Guide issued by HKEX (2023). This article also provides the following managerial implications for listed companies, investors and other stakeholders to promote the coordinated development of ESG disclosure. First, for listed companies, our findings show although the use of blockchain occurs cost, the benefits generated by transparent and high-quality disclosure will help corporates achieve more opportunities to be promoted to the investors in the blockchain platform and thus attract more investors to invest in the corporates. Listed companies may consider hiring senior managers who can accept more risk and being slightly risk-seeking can earn greater bonus rate and thus more expected benefits. Second, for investors, they will have higher quality of ESG reports provided by listed companies and the blockchain technology helps investors to have more confidence in the authenticity of quality level. Investors could make their investment decisions after analyzing the risk averse attitude to token value of listed companies. Third, for the other ESG stakeholders, such as regulators, consultants, and rating agencies, the incentive scheme proposed in this study may be considered to improve the overall quality of ESG disclosure and efficiency of ESG supervision. We suggest regulators to concentrate more on the token market and publish more regulations to decrease the fluctuation of token value in case that some listed companies choose to pay less effort to generate ESG reports. As consultants and rating agencies are both stakeholders to provide ESG disclosure services, we suggest them to have more confidence in token value applied in blockchain-based ESG disclosure to establish a stable token environment.

7.4 | Limitations and future research

The study has several limitations. First, the credibility of ESG data recorded on the blockchain platform may be influenced by opportunistic behavior. Although this study assumed the risk of uploading incorrect ESG data is not considered, in the practical scenarios, it is an inevitable factor in ESG disclosure. Second, the proposed crypto token in this study is currently a novel concept in ESG disclosure and the entire issuing and financing system are still required to further develop. Third, the second-best optimal solutions for designing contracts are too complex to analyze the impact of risk attitude and external environment on listed companies' business management decisions in a clearer and more intensive way.

In the future, the work can be further extended based on the limitations. First, the risk of opportunistic behavior should be considered in the future research if we adopt the exist technology. If not, we could consider the use of new technology of IoT to achieve more real-time and authentic data. Second, this study concentrates on designing a static incentive mechanism which could be beneficial to investors and listed companies to make optimal decisions in ESG disclosure. However, ESG disclosure is a long term value creation activity (Albitar et al., 2020), a dynamic incentive mechanism deserves a further research to help make the optimal decisions in the whole process. In the dynamic game process, how to define the token value and develop the issuing and financing system should be considered. Third, smart contract technology could be utilized to calculate the solutions automatically and efficiently. More importantly, the relation of corporate social responsibility and megaproject social responsibility (Cottafava et al., 2023) could be considered to analyze more comprehensive managerial insights and some relevant factors may be merged to simplify the model calculation.

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APPENDIX A: All proofs

The purpose of this Appendix is to prove Lemma 4.1 and 4.2.

Proof of Lemma 4.1

From (12), we have $\max U_{lc} = \max t_0 + b\lambda \ln a - \frac{1}{2}ma^2 + u_a$.

For a given b, since $d^2U_{lc}(a)/da^2 = -m - \frac{b\lambda}{a^2} < 0$, which implies that U_{lc} is concave. Solving the first order condition yields the optimal effort a for given b: $dU_{lc}(a)/da = 0 \rightarrow a^*_{FB} = \sqrt{\frac{b\lambda}{m}}$.

From (14), we have $t_0 + b\lambda \ln a - \frac{1}{2}ma^2 + u_a = u_0$, then $t_0 = -b\lambda \ln a + \frac{1}{2}ma^2 - u_a + u_0$.

From (11), we have $\max U_{inv} = \max u_p - t_0 - c_{bc} + \lambda \ln a - b\lambda \ln a$. Putting $t_0 = -b\lambda \ln a + \frac{1}{2}ma^2 - u_a + u_0$, and $a^*_{FB} = \sqrt{\frac{b\lambda}{m}}$ into (11), and solving the first order condition with respect to b, we have $b = 1$. Then we have $t_0 = u_0 - u_a + \frac{\lambda}{2}\left(1 - \ln\frac{\lambda}{m}\right)$.

Proof of Lemma 4.2

From (18), we have $\max t_0 + b\lambda \ln a - \frac{1}{2}ma^2 + u_a + \theta_a\sigma(t_0 + b\lambda \ln a) - \frac{1}{2}\theta_a b^2\sigma^2$.

For a given b, since $d^2U_{lc}(a)/da^2 = -\frac{b\lambda}{a^2} - m - \frac{b\theta_a\sigma\lambda}{a^2} < 0$, which implies that U_{lc} is concave. Solving the first order condition yields the optimal effort a for given b: $dU_{lc}(a)/da = 0 \rightarrow a^*_{SB} = \sqrt{\frac{b\lambda(1+\theta_a\sigma)}{m}}$.

From (20), we have $t_0 + b\lambda \ln a - \frac{1}{2}ma^2 + u_a + \theta_a\sigma(t_0 + b\lambda \ln a) - \frac{1}{2}\theta_a b^2\sigma^2 = u_0$. Then we have $t_0{}^* = \frac{-b\lambda \ln a + \frac{1}{2}ma^2 - u_a - \sigma b\lambda \ln a + \frac{1}{2}\theta_a b^2\sigma^2 + u_0}{1+\theta_a\sigma}$.

From (17), we have $\max U_{inv} = \max u_p - t_0 - c_{bc} + \lambda \ln a - b\lambda \ln a$. Putting $a^*_{SB} = \sqrt{\frac{b\lambda(1+\theta_a\sigma)}{m}}$ and $t_0{}^* = \frac{-b\lambda \ln a + \frac{1}{2}ma^2 - u_a - \sigma b\lambda \ln a + \frac{1}{2}\theta_a b^2\sigma^2 + u_0}{1+\theta_a\sigma}$ into (17), solve the first order condition with respect to b, we have $b^* = \frac{-\lambda - \theta_a\sigma\lambda + \sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda + \theta_a\sigma\lambda + 8\theta_a\sigma^2}}{4\theta_a\sigma^2}$.

Putting $b^* = \frac{-\lambda - \theta_a\sigma\lambda + \sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda + \theta_a\sigma\lambda + 8\theta_a\sigma^2}}{4\theta_a\sigma^2}$ into $a^*_{SB} = \sqrt{\frac{b\lambda(1+\theta_a\sigma)}{m}}$, we have $a^*_{SB} = \sqrt{\frac{-\lambda - \theta_a\sigma\lambda + \sqrt{1+\theta_a\sigma}\sqrt{\lambda}\sqrt{\lambda + \theta_a\sigma\lambda + 8\theta_a\sigma^2}}{4\theta_a\sigma^2}}\sqrt{\frac{\lambda(1+\theta_a\sigma)}{m}}$.