Analysis of Heteronomy Strategies for Platform Corporate Social Responsibility Under Government Intervention

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ABSTRACT With the change in emerging technology and the economic environment, governance of the lack and alienation of platform corporate social responsibility has become more urgent. Firstly, this paper analyses the autonomy defects of the platform corporate social responsibility and illustrates the need for heteronomy of platform corporate social responsibility. Secondly, we use differential game to study the heteronomy strategies for platform corporate social responsibility: self-beneficial governance or co-beneficial governance, including the optimal governance effort level and optimal profit and optimal trajectory of the amount of governance. Then, numerical examples are used to compare the two situations. Finally, the conclusion is verified by SFIC model. The result shows that: (1) The amount of governance gradually reaches a stable state over time. (2) Co-beneficial governance can improve the heteronomy of platform corporate social responsibility. (3) The maturity of the ecosystem in which the governance subject and platform corporation are located positively affects the amount of governance.

INDEX TERMS Heteronomy strategies, platform corporate, corporate social responsibility, differential game.

I. INTRODUCTION
The development of the platform and sharing economies has become a significant force in promoting corporate development, and many platform corporations have emerged. Platform corporations use the platform to connect bilateral or multilateral users, which can allocate resources more efficiently and reduce process costs, and rely on various innovations [1], [2], [3], such as business models, to obtain higher economic benefits. With the development of platforms and digitalization, personal information leakage and commercial non-compliance have come to light alongside technological innovation. Thus, there is an urgent need to strengthen the supervision of the industry. For example, some platform corporations illegally collect user information, damage users’ rights and interests, and unfair competition on e-commerce platforms destroys the operating environment. Therefore, platform corporations must exercise financial functions based on commercial behavior, pay attention to their responsibilities’ performance, and actively undertake social responsibilities [4]. To strengthen the regulation of the new industry and protect consumer rights, the State Council has taken the lead, and several ministries are involved in the law of the “platform economy”. At the same time, platform corporations’ lack and alienation of social responsibility have become prominent, seriously hindering the development of the economy [5], [6]. According to relevant statistics, back in 2014, the economic losses caused by the lack of integrity of Chinese enterprises exceeded RMB 600 billion per year. The issue of platform corporate social responsibility...
is gradually gaining the attention of all sectors of Chinese society.

Large-scale platform corporations have more major social responsibilities owing to their larger user scale, broader business scope, and larger economic volume. In contrast, small platform companies have relatively little social responsibility, and governance takes place mainly in cluster governance. Based on the impact of social responsibility, this study limited the scale of platform corporations. The platform corporation referred to in this study is limited to large platform corporations. For platform corporations, the rise of the sharing economy has given new content to their social responsibility. Corporate social responsibility is the role of a corporation in social interests, expressed through relevant corporate policies and practices [7]. In recent years, the number of social responsibility reports issued by Chinese corporations has increased, marking the gradual recovery of corporate responsibility. Therefore, the relevant indicators in corporate social responsibility reports can measure the amount of social responsibility governance, including the increase in governance mechanisms, cooperation with other stakeholders, social activities, and malicious competition management. The social responsibility of platform corporations emphasizes that they are responsible for the interests of others, including the social environment and other partners. In business activities through the platform, the platform corporation must maintain its security and respond to various needs requiring autonomous governance. The corporation is the platform manager and plays the role of a “multiplicity” of market resources [8]. Formulating access rules for bilateral users controls the transaction process of bilateral users, provides technical support, and develops incentive mechanisms. Because the platform corporation can provide trading places for the market supply and demand sides through the platform, it can accurately connect the supply and demand sides and reduce the market transaction cost. Platform corporate fulfillment of social responsibility helps improve corporate image, encourages other stakeholders to invest more resources, and improves corporate performance. Therefore, corporate social responsibility aims to achieve the coupling and improvement of economic and social benefits. In addition, one of the bases for establishing the game model is the interesting relationship of the governance subject; therefore, in the governance of social responsibility, we mainly focus on economic interests. Thus, the platform corporate social responsibility studied in this paper refers to the moral responsibility of platform corporations to harm the interests of others and affect the economic interests of others through their advantageous position or raising the access threshold in commercial transactions. However, there are some limitations to relying only on the autonomous governance of platform corporations. For example, platform companies use their dominant position and power to bring about security and monopoly [9] problems, such as inhibition of innovation and data leakage, disrupting the market order. Corporate social responsibility should consider not only internal governance mechanisms but also external governance mechanisms [10].

The corporate social responsibility content of corporate social responsibility of the platform and the root causes of autonomy defects are shown in Figure 1. The fundamental reason for defects in the autonomous governance of platform companies is the unequal relationship between platform companies and other stakeholders driven by profit. The main manifestations are as follows: on the one hand, platform companies abuse their strong position in the market, resulting in monopolistic behaviors that harm the interests of bilateral users. To pursue economic benefits and seize market share, platform companies control supply side users by improving access conditions and seeking economic benefits by weakening the choice of demand-side users. In addition, platform companies force participants to withdraw from other platforms through abnormal means, preventing regular competition between companies. However, from the perspective of the sharing and openness of the platform [11], digitization and intelligence have accelerated the platform’s openness, and the virtual characteristics of digital platforms have made governance more complicated. Illegal transactions may threaten the interests of data-asset owners, thereby endangering social and public security. Large platform companies have become deeply rooted in the regional economic market because of their ability to contribute fully to the development of the regional economy. As a ‘partner’ of the government, the division of rights and responsibilities has become one of the most pressing issues to be addressed. As the openness of platform resources breaks through the boundaries of traditional commercial transactions, the
flow of platform resources is no longer restricted by time, space, or geography. A platform corporation relying only on self-awareness may produce other harmful behaviors from external stakeholders, such as monopoly and unsatisfactory performance of responsibilities. Therefore, the participation of external stakeholders is needed to improve the awareness of social responsibility and willingness to contribute to the corporate platform and supervise and punish the lack of social responsibility and alienation.

This manuscript differs from the existing social responsibility governance research from the perspective of internal corporate members. It takes the government, public, and bilateral users as the subjects in the heteronomy of platform corporate social responsibility. It also examines the strategic choices of subjects in the heteronomy of platform corporate social responsibility. We will investigate which of the self-beneficial and co-benefit governance approaches is more conducive to the heteronomy of platform corporate social responsibility. This paper uses the differential game method to obtain the optimal governance quantity and profitability trajectory. Finally, the impact of each parameter on the amount and profitability of governance was analyzed using simulations. This paper’s main contributions and innovations are summarized as follows: (1) Extract the stakeholders of platform corporate social responsibility governance from the perspective of platform ecology, not just from the supply chain perspective or other individual interest partners, including more subjects. (2) Study social responsibility governance from a heteronomy governance and dynamic perspective and add a mathematical description to enrich the relevant literature on platform corporate social responsibility governance. (3) By describing the interesting relationship of the subjects in social responsibility governance and the trajectory of governance volume and total profit, this paper attempts to obtain each subject’s behavior strategies, improve governance efficiency, and provide a theoretical basis for the governance strategies of the subject. The remainder of this paper is structured as follows: the relevant literature review and research framework are presented in the second part, and then the differential game models of the two decision-making modes are provided in the third part. The fourth part presents a comparative analysis, the fifth part presents an analysis of calculation examples, and the sixth part presents the research conclusion.

II. LITERATURE REVIEW AND RESEARCH FRAMEWORK
A. LITERATURE REVIEW
Research on corporate social responsibility has mainly been conducted from the perspective of internal corporate governance. For example, researchers such as Farman Ullah Khan [12] studied the effect of senior managers’ heterogeneous rights on corporate social responsibility performance. Ju Hyoung Park [13] believes that corporate social responsibility activities can increase corporate value and points out that the stronger the nepotism of corporate directors, the more negative the impact on the amount of weight.

Seckin-Halac et al. [14] argued that female directors in business have a beneficial impact on corporate social responsibility. The rate of parental leave is inversely proportional to corporate social responsibility. In terms of platform corporate social responsibility, the researcher Yibin Li and others believe that platform corporate social responsibility can improve employees’ innovation performance [15]. Some researchers have studied the interaction between corporate performance, corporate governance, and corporate social responsibility. Ma [16] and other researchers have pointed out the internal mechanism of corporate governance regulating the relationship between corporate social responsibility and corporate performance. Jamali believes that corporate governance and corporate social responsibility have a two-way effect [17].

In addition, in the research of corporate social responsibility governance, some researchers believe that stakeholders need to consider the role of the main body in the supply chain and the government. For example, Sen et al. referred to stakeholders, including employees, customers, and investors in their study [18]. The researcher, NIA Menezes Montenegro, examines corporate tax evasion and corporate social responsibility from national governance. The stronger the government’s governance and supervision ability, the more it can restrain corporate tax evasion [19]. The relevant personnel of social responsibility usually vary across industries. Researchers believe that the appropriate personnel for social responsibility include raw material suppliers and distributors [20]. Monika has considered the food industry as the research background and believes that food processors, retailers, and citizens pay more attention to ecological problems [21].

In terms of governance mode, from the perspective of subject relationships, scholars have put forward three governance modes of social responsibility in the supply chain system, namely decentralized, centralized, and collaborative. In collaborative governance, a change in the decision-making of each member affects the profits of other members. The ultimate goal of collaborative governance is to ensure the highest overall profit in the supply chain [22]. In addition, scholars have considered the issue of social responsibility in corporate technology R&D and proposed different R&D strategies based on subject relations [23]. From the perspective of institutional design and internal structure, most studies examine the governance model of platform companies and bilateral users from a bilateral market perspective, where the goal is mainly to maximize commercial profits and the governance structure is relatively simple. From the suppliers’ perspective, some scholars have proposed two governance mechanisms: evaluation and cooperation [24]. Other researchers have proposed models such as single-headed structures and their application scenarios [25]. Some scholars have also studied the governance of social responsibility from a status-role perspective, emphasizing the governance status and function of governing subjects [26]. From existing research, studying governance models from the perspective
of a corporation alone does not fully encompass all possible governance situations, which requires research using the perspectives of multiple subjects.

In terms of methods, the differential game is used in the decision-making process with two roles: leader and follower, which is used in the strategy selection and coordination of stakeholders such as insurance, supply chain, and transportation. Bai et al. used the differential game method to study international cooperation to control wastewater and waste gas pollution [27]. Sun et al. used a differential game to study the ecological compensation of river basin pollution and analyzed the strategic choices of the government and firms [28]. Researchers Yao used a differential game to study the coordination mechanism of a low-carbon supply chain [29]. Researchers have used a differential game model to study the pursuit and flight problem of multiple players [30]. Cheng and Ding constructed a competition model of two supply chains, studied corporate social responsibility decision-making, and proved that social responsibility can realize the sustainable development of the supply chain [31].

Li studied the impact of government subsidies on corporate social responsibility in the supply chain by constructing a differential game model between manufacturers and retailers [32]. Bertinelli et al. used the differential game method to study the national strategic behavior of reducing carbon dioxide emissions [33]. The differential game is suitable for situations in which the government is dominant and public and bilateral users follow. Based on the perspective of stakeholders in the ecosystem, this study examines heteronomy strategies for platform corporate social responsibility under government leadership. Combined with scholars’ application of differential games [34], [35], [36] using the differential game model, considering the two situations of self-beneficial governance and collaborative governance among the government, bilateral users, and the public, compared with the two governance situations.

B. RESEARCH FRAMEWORK

This platform has become essential for companies to improve their competitiveness by joining multilateral partners in innovation activities. Therefore, joining an ecosystem [37] in which a platform corporation is the center and targets innovation activities (including technological innovation, product innovation, and service innovation) becomes an inevitable choice for corporations and partners to achieve the goal of sustainable development. In the platform company ecosystem, participants create value through cooperation and competition, and all participants are resource providers and innovation beneficiaries. Because of the dominant position of platform firms in the ecosystem, most studies examine the relationship between bilateral users and platform firms from the perspective of platform firms. With the participation of bilateral users, firms no longer obtain value mainly through internal research and development of technology, as traditionally recognized, but instead through bottom-up innovation, thus achieving a win-win situation for multiple actors. Since the lack of social responsibility and alienation of platform companies in this system threatens the interests of many subjects, the perspectives of other stakeholders in the ecosystem are used to study the governance of platform companies, showing sufficient rationality. As Chrislip and Larson point out, the first condition for successful collaboration is that all stakeholders affected by or concerned about the problem must be broadly included [38]. Awareness of sustainable development is a collective responsibility [39]. Companies need to be concerned about the common interests of stakeholders [40]. Many scholars believe that stakeholders in corporate governance include shareholders, employees, and other internal stakeholders. Due to the externality of social responsibility itself, we must consider corporate social responsibility governance from the perspective of external subjects. Scholars have proposed the ecological governance paradigm of social responsibility as support for this idea. Thus, government departments, bilateral users, and the public can govern platform corporations.

Clarify the leading role of the government. In China, corporate social responsibility is primarily designated by regulatory authorities to provide norms for platform corporations. Currently, this is primarily led by the government. The government sector is in a dominant position in the governance [41], [42] of platform corporate social responsibility, and any actions of platform corporate belong to the scope of government management. Government regulations are usually mandatory, and the government has administrative enforcement strength to legislate on social responsibility issues with more vital credibility.

Clarify the roles of public and bilateral users. Inadequate external regulation is one of the key factors leading to a lack of social responsibility for platforms. There is a need to improve the external regulatory network and reduce the regulatory risk of platform companies, bilateral users, and the public to play to their respective strengths and participate in the governance of platform companies. Moreover, government departments support the supervision and rights of the public and users through incentives in the governance of platform corporate social responsibility, which can effectively reduce the risk of insufficient supervision of platform corporate social responsibility.

III. MODEL DESCRIPTION

A. PROBLEM DESCRIPTION

Based on the above analysis, this study takes government, the public, and bilateral users as the object to study the heteronomy of platform corporate social responsibility. The research approach is illustrated in Figure 2.

Figure 2 shows that there are two ways of governance for the heteronomy of platform corporate social responsibility. One is self-beneficial governance and the other is co-beneficial governance. Consider that the government department is dominant and shares the cost of governance for both users and the public. In self-beneficial governance, governing subjects pursue maximization of their interests.
In co-beneficial governance, the governing subjects seek to maximize their overall interests.

B. BASIC ASSUMPTIONS

Assumption 1: It is assumed that $C_b(t), C_s(t),$ and $C_g(t)$ are the cost of governance for bilateral users, the cost of monitoring by the public, and the cost of government support, respectively. Furthermore, the degree of governance effort of bilateral users at time $t$ is defined as $E_b(t)$ and the degree of governance effort of the public and government at time $t$ is defined as $E_s(t)$ and $E_g(t)$, respectively. The cost coefficients of governance effort for the three parties are denoted as $k_b, k_s,$ and $k_g$, respectively. Therefore, according to existing studies [43], the cost function of governance at time $t$ is expressed as:

$$C_b(t) = \frac{1}{2} k_b E_b^2 (t)$$  \hspace{1cm} (1)

$$C_s(t) = \frac{1}{2} k_s E_s^2 (t)$$  \hspace{1cm} (2)

$$C_g(t) = \frac{1}{2} k_g E_g^2 (t)$$  \hspace{1cm} (3)

Assumption 2: The amount of governance is expressed as $T(t)$. $g$ denotes the impact of the government’s governance effort on the amount of governance and $\delta$ denotes the natural rate of decay of the amount of governance. Since the governance policies of platform companies are set by the government, the differential equation for the process of change in the amount of governance is expressed as

$$T(t) = g E_g(t) - \delta T(t)$$  \hspace{1cm} (4)

Assumption 3: The initial benefit is 0, $\mu$ denotes the coefficient of influence of the amount of governance on governance revenue, $s$ denotes the coefficient of influence of public scrutiny on governance revenue, $b$ denotes the coefficient of influence of bilateral users on governance revenue, and $l$ denotes the development stage of the ecosystem. The revenue of governance is expressed as

$$R(T(t), E_s(t), E_b(t)) = \left[ \mu T(t) + s E_s(t) + b E_b(t) \right] \cdot l$$  \hspace{1cm} (5)

Assumption 4: $\alpha(t)$ and $\beta(t)$ denote the government’s share of bilateral user and public governance costs at time $t$, $\alpha(t) < 1$, and $\beta(t) < 1$.

Assumption 5: The discount rate is $r$, and the revenue distribution rates of bilateral users, the public, and the government are $n_b, n_s,$ and $n_g$, respectively.

C. ANALYSIS OF SELF-BENEFICIAL GOVERNANCE PROCESSES

In a state of self-beneficial governance, the government is the prominent leader responsible for formulating macro-policy governance, including incentives for bilateral users and the public, such as reduction and exemption of related fees. Citing the numerical expression of the subject relation proposed by Jiang Yue and other scholars from China [44], the bilateral users and the public determine their governance efforts, and the profit functions of the bilateral users, the public, and the government are as follows:

$$J_b = \int_0^\infty e^{-rt} \left[ n_b R(T(t), E_s(t), E_b(t)) - \frac{1}{2} (1 - \alpha) k_b E_b^2 (t) \right] dt$$  \hspace{1cm} (6)

$$J_s = \int_0^\infty e^{-rt} \left[ n_s R(T(t), E_s(t), E_b(t)) - \frac{1}{2} (1 - \beta) k_s E_s^2 (t) \right] dt$$  \hspace{1cm} (7)

$$J_g = \int_0^\infty e^{-rt} \left[ n_g R(T(t), E_s(t), E_b(t)) - \frac{1}{2} k_g E_g^2 (t) - \frac{\beta}{2} k_s E_s^2 (t) - \frac{\alpha}{2} k_b E_b^2 (t) \right] dt$$  \hspace{1cm} (8)
Theorem 1

The optimal strategies for governance subjects in the case of self-beneficial governance are as follows:

\[
\begin{align*}
\alpha &= \frac{2n_b - n_s}{2n_b + n_s} \quad \beta = \frac{2n_b - n_s}{2n_b + n_s} \\
E_b &= \frac{lb (2n_b + n_b)}{2k_b} \quad E_s = \frac{ls (2n_b + n_s)}{2k_s} \\
E_g &= \frac{n_g \mu g l}{k_g (r + \delta)} \quad (9)
\end{align*}
\]

The optimal trajectory of the change process of the amount of governance is:

\[
T^u(t) = (T_0 + \frac{n_g \mu g^2 l}{-\delta k_g (r + \delta)}) e^{-rt} - \frac{n_g \mu g^2 l}{-\delta k_g (r + \delta)} \quad (10)
\]

The optimal profit of bilateral users is:

\[
J^u_b = e^{-rt} (a^u_b T^u + b^u_b) \quad (11)
\]

The optimal profit of public is:

\[
J^u_s = e^{-rt} (a^u_s T^u + b^u_s) \quad (12)
\]

The optimal profit of governance is:

\[
J^u_g = e^{-rt} (a^u_g T^u + b^u_g) \quad (13)
\]

The optimal profit of self-beneficial governance is

\[
J_u = J^u_b + J^u_s + J^u_g \quad (14)
\]

where

\[
\begin{align*}
a^u_b &= \frac{n_b \mu l}{r + \delta} \quad a^u_s = \frac{n_s \mu l}{r + \delta} \quad a^u_g = \frac{n_g \mu l}{r + \delta} \\
b^u_b &= \frac{l^2 s^2 n_b (2n_b + n_s)}{2r k_b} + \frac{l^2 b^2 n_b (2n_b + n_s)}{4r k_b} + \frac{a_b a_g g^2}{r k_g} \\
b^u_s &= \frac{l^2 s^2 n_s (2n_b + n_s)}{4r k_s} + \frac{l^2 b^2 n_s (2n_b + n_s)}{2r k_s} + \frac{a_s a_g g^2}{r k_g} \\
b^u_g &= \frac{l^2 s^2 (2n_b + n_s)^2}{8r k_s} + \frac{l^2 b^2 (2n_b + n_s)^2}{8r k_b} + \frac{a_g^2 g^2}{2r k_g} \quad (15)
\end{align*}
\]

Proof

The dynamic stochastic control method is used to solve the problem, and the profit optimization functions of bilateral users, the public, and government departments at time \( t \) are (16)–(18), as shown at the bottom of the next page.

Satisfy the following HJB equation as in (19)–(21), shown at the bottom of the next page.

Taking the partial derivatives for the HJB equations \( E_b, E_s \) and \( E_g \) respectively:

\[
\begin{align*}
\alpha &= \frac{2n_b - n_s}{2n_b + n_s} \quad \beta = \frac{2n_b - n_s}{2n_b + n_s} \\
E_b(t) &= \frac{lb n_b}{(1 - \alpha) k_b} \quad E_s(t) = \frac{lb n_s}{(1 - \beta) k_s} \quad E_g(t) = \frac{V'_g}{k_g} \quad (22)
\end{align*}
\]

Eventually, by substituting (23) into (22), (9) in Theorem 1 is proved.

Substituting (22) and (23) into (19), (20), and (21), we obtain:

\[
\begin{align*}
rV_b(x) &= n_b \mu T + \frac{l^2 s^2 n_b (2n_b + n_s)}{2k_b} + \frac{l^2 b^2 n_b (2n_b + n_s)}{4k_b} + \frac{V'_g V'_g g^2}{k_g} - V'_b \delta T \quad (24) \\
rV_s(x) &= n_s \mu T + \frac{l^2 b^2 n_s (2n_b + n_s)}{4k_s} + \frac{V'_s V'_s g^2}{2k_g} - V'_s \delta T \quad (25) \\
rV_g(x) &= n_g \mu T + \frac{l^2 b^2 (2n_b + n_s)^2}{8k_b} + \frac{l^2 s^2 (2n_b + n_s)^2}{8k_s} + \frac{V'_g V'_g g^2}{2k_g} - V'_g \delta T \quad (26)
\end{align*}
\]

Obtain the solutions to (24), (25), and (26). It turns out to be a binary one-degree function of \( T \). Let

\[
\begin{align*}
V_b(x) &= a_b T + b_b \\
V_s(x) &= a_s T + b_s \\
V_g(x) &= a_g T + b_g
\end{align*}
\]

\( a_b, a_s, a_g, b_b, b_s, \) and \( b_g \) are constants. Then:

\[
\begin{align*}
a^u_b &= \frac{n_b \mu l}{r + \delta} \quad a^u_s = \frac{n_s \mu l}{r + \delta} \quad a^u_g = \frac{n_g \mu l}{r + \delta} \\
b^u_b &= \frac{l^2 s^2 n_b (2n_b + n_s)}{2r k_b} + \frac{l^2 b^2 n_b (2n_b + n_s)}{4r k_b} + \frac{a_b a_g g^2}{r k_g} \\
b^u_s &= \frac{l^2 s^2 n_s (2n_b + n_s)}{4r k_s} + \frac{l^2 b^2 n_s (2n_b + n_s)}{2r k_s} + \frac{a_s a_g g^2}{r k_g} \\
b^u_g &= \frac{l^2 s^2 (2n_b + n_s)^2}{8r k_s} + \frac{l^2 b^2 (2n_b + n_s)^2}{8r k_b} + \frac{a_g^2 g^2}{2r k_g} \quad (30)
\end{align*}
\]

Eventually, (11), (12) and (13) of Theorem 1 is proved. Then, substituting \( b^u_g \) back to (29) we obtain:

\[
E_g = \frac{n_g \mu g l}{k_g (r + \delta)} \quad (31)
\]

Substituting (31) back to (4) we obtain:

\[
T^u(t) = -\delta T + \frac{n_g \mu g^2 l}{k_g (r + \delta)} \quad (32)
\]

Solving equation (32), the optimal trajectory of the change process of the amount of governance is obtained as follows:

\[
T^u(t) = (T_0 + \frac{n_g \mu g^2 l}{-\delta k_g (r + \delta)}) e^{-rt} - \frac{n_g \mu g^2 l}{-\delta k_g (r + \delta)} \quad (33)
\]

Eventually, (10) of Theorem 1 is proved.
D. ANALYSIS OF CO-BENEFICIAL GOVERNANCE PROCESS

Theorem 2
The optimal strategies of governance subjects in the case of cooperative governance are:
\[
E_c^* = \frac{s}{k_s} E_b^* = \frac{bl}{k_b}, \quad E_c^* = \frac{\mu g l}{k_c (r + \delta)} \quad (34)
\]

The optimal trajectory of the change process of amount of governance is:
\[
T_c^u = \left(T_0 + \frac{\mu g l^2}{-k_c (r + \delta) \delta} \right) e^{-rt} - \frac{\mu g l^2}{-k_c (r + \delta) \delta} \quad (35)
\]
The optimal profit of co-beneficial governance is:
\[
J_c^u = e^{-rt} \left(a_c^u T + b_c^u \right) \quad (36)
\]
where
\[
a_c^u = \frac{\mu l}{r + \delta}, \\
b_c^u = \frac{s^2 l^2}{2r k_b} + \frac{s^2 l^2}{2r k_b} + \frac{a_c^2 g^2}{2r k_c}
\]

Proof
In co-beneficial governance, the decision-making goal is to maximize the profits of the three parties, and the profit functions are as follows:
\[
J_c^u = \int_0^\infty e^{-rt} \left[R(T(t), E_c(t), E_b(t)) - \frac{1}{2} k^2_b E_c - \frac{1}{2} k^2_s E_b - \frac{1}{2} k^2_s E_c \right] dt \quad (37)
\]
Satisfy the following HJB equation:
\[
rV_c = \max_{E_b, E_c, E_g} \left[(\mu T(t)l + sE_c(t)l + bE_b(t))l \right. \\
\left. - \frac{1}{2} k^2_b E_b - \frac{1}{2} k^2_s E_c - \frac{1}{2} k^2_s E_c \right] \quad (38)
\]

Taking the partial derivatives for the HJB equations \(E_b\), \(E_c\) and \(E_g\) respectively:
\[
E_b^c = \frac{bl}{k_b}, \quad E_c^c = \frac{sl}{k_s}, \quad E_g^c = \frac{V'_c g}{k_g} \quad (39)
\]
Substituting (39) back to (38), then we obtain as in (40), shown at the bottom of the next page. From (40), is a binary one-degree function of \(T\). Let
\[
V_c = a_c T + b_c \quad (41)
\]
Substituting (41) back to (40), then we obtain:
\[
r(a_c T + b_c) = \mu T(t)l + s^2 l^2 + b^2 l^2 \frac{s^2 l^2}{2k_b} - \frac{b^2 l^2}{2k_b} - \frac{a_c^2 g^2}{2k_c} + \frac{a_c^2 g^2}{2k_c} - a_4 \delta T \quad (42)
\]
\(a_c^u, b_c^u\) are constants. Then:
\[
a_c^u = \frac{\mu l}{r + \delta}, \\
b_c^u = \frac{s^2 l^2}{2r k_b} + \frac{s^2 l^2}{2r k_b} + \frac{a_c^2 g^2}{2r k_c} \quad (43)
\]
Eventually, (36) of Theorem 2 is proved.
Then, substituting (43) back into \(E_c^c\) in (39), we obtain:
\[
E_g^c = \frac{\mu g l}{k_c (r + \delta)} \quad (44)
\]
Eventually, (34) of Theorem 2 is proved.
Substituting (44) back to (4), then we obtain:
\[
T_c^u(t) = -\delta T + \frac{\mu g l^2}{k_c (r + \delta) \delta} \quad (45)
\]
Solving (45), the optimal trajectory of the change process of governance quantity is obtained as follows:
\[
T_c^u(t) = \left(T_0 + \frac{\mu g l^2}{k_c (r + \delta) \delta} \right) e^{-rt} - \frac{\mu g l^2}{k_c (r + \delta) \delta} \quad (46)
\]
Eventually, (35) of Theorem 2 is proved.

\[
J_b^u = e^{-r(t-t_0)} \int_0^{\infty} \left[n_b R(T(t), E_b(t), E_c(t)) - \frac{1}{2} \left(1 - \alpha \right) k_b E_b(t)^2 \right] dt \quad (16)
\]
\[
J_c^u = e^{-r(t-t_0)} \int_0^{\infty} \left[n_c R(T(t), E_c(t), E_b(t)) - \frac{1}{2} \left(1 - \beta \right) k_c E_c(t)^2 \right] dt \quad (17)
\]
\[
J_g = e^{-r(t-t_0)} \int_0^{\infty} \left[-\frac{1}{2} k_c E_c(t)^2 - \frac{1}{2} k_b E_b(t)^2 \right] dt \quad (18)
\]

\[
rV_b(x) = \max_{E_b} \left\{n_b R(T(t), E_b(t), E_c(t)) - \frac{1}{2} \left(1 - \alpha \right) k_b E_b(t)^2 + V'_b \left( g E_b - \delta T(t) \right) \right\} \quad (19)
\]
\[
rV_c(x) = \max_{E_c} \left\{n_c R(T(t), E_c(t), E_b(t)) - \frac{1}{2} \left(1 - \beta \right) k_c E_c(t)^2 + V'_c \left( g E_c - \delta T(t) \right) \right\} \quad (20)
\]
\[
rV_g(x) = \max_{E_g} \left\{-\frac{1}{2} k_c E_c(t)^2 + V'_c \left( g E_g - \delta T(t) \right) \right\} \quad (21)
\]
IV. RESULT ANALYSIS AND DISCUSSION

A. COMPARISON OF TWO SITUATIONS

The following propositions are obtained by comparing the optimal strategies of governance subjects, the optimal trajectory of the change process of governance quantity, optimal profit of co-beneficial governance, and self-beneficial governance:

Proposition 1

When \( \alpha > \frac{2n_{u} - n_{b}}{2} \) and combined with (22), since the revenue distribution rate is constantly greater than 0, it is concluded that \( E_{n} > E_{b}, E_{s} > E_{i}, E_{g} > E_{k}, T_{c} > T_{u}, J_{a} \geq J_{u} \).

From Proposition 1, the degree of governance effort of the three subjects at time \( t \), the amount of governance, and profit are higher in the case of co-beneficial governance than in the case of self-beneficial governance. This shows that co-beneficial governance can enhance a government’s enthusiasm for governance. The government will invest more effort in managing the lack and alienation of the social responsibility of platform corporations. Co-beneficial governance will improve the overall profit of the government, public, and bilateral users and promote an increase in social responsibility issues.

The degree of effort of both users and the public depends on the percentage of government subsidies. However, some conditions must be satisfied to ensure that the government, public, and bilateral users voluntarily participate in the governance process. This condition implies that the profits of the government, public, and bilateral users in the co-beneficial state are higher than those in the self-beneficial state.

Proposition 2

The degree of governance effort of the public and bilateral users \( E_{i}(t), E_{b}(t) \) in the co-beneficial and self-beneficial cases is positively correlated with the coefficient of influence on governance revenue \( s, b \), development stage of the ecosystem \( l \), and revenue distribution rate \( n_{i} \), and negatively correlated with the cost coefficients of governance effort for public and bilateral users \( k_{i}, k_{b} \). The degree of governance effort of the public and government \( E_{g}(t) \) in the co-beneficial and self-beneficial cases is positively correlated with the impact of the government’s governance effort on the amount of governance \( g \), revenue distribution rate \( n_{b} \), development stage of the ecosystem \( l \), and coefficient of influence of the amount of governance on governance revenue \( \mu \). The degree of governance effort of the public and government \( E_{g}(t) \) in the co-beneficial and self-beneficial cases is negatively correlated with the cost coefficients of the government’s governance effort \( k_{g} \), the natural rate of decay of the amount of governance \( \delta \), and the discount rate \( \rho \).

In both the co-beneficial and self-beneficial cases, optimal profit is positively related to the coefficient of influence of governance volume on governance revenue, development stage of the ecosystem \( l \), and revenue distribution rate \( n_{i} \), and negatively related to the cost coefficients of governance effort \( k_{i} \), discount rate \( \rho \), and natural rate of decay of the amount of governance \( \delta \).

B. NUMERICAL VERIFICATION

To further analyze the decision results in both cases, several examples are used to demonstrate the changes in the amount and profit of governance, along with the MATLAB simulation software to perform simulations. Because it is difficult to obtain real data on the corporate social responsibility governance of the platform, the setting of simulation parameters is based on the analysis of the action mechanism of the governance subject and considering the impact of other aspects. First, we consider the characteristics of the variables in the model. Second, referring to a related study [45], [46], [47], assume that the initial amount of governance is zero and the sum of the revenue of the governance rate is 1. In addition, other parameters are assigned as follows: \( k_{b} = 22, k_{i} = 18, k_{g} = 12, \mu = 2, s = 3, b = 1, l = 5, g = 2, n_{b} = 0.4, n_{i} = 0.4, n_{g} = 0.2, r = 0.8, \delta = 1 \).

Figure 4 shows the change in optimal profit over time in the two cases. The profits of both co-beneficial and self-beneficial governance show a decreasing trend from a specific value to zero because, as the volume of governance increases over time, the demand for governance decreases, resulting in a decrease in revenue. Clearly, as the volume of governance increases, the benefits to the subject of governance decrease. As governance increases, the lack and alienation of social responsibility become fully managed. This phenomenon shows that social responsibility pursues social goals and conflicts with commercial interest.
FIGURE 5. Comparison of trends in the amount of governance under two situations.

Figure 5 shows the change in the amount of governance of the lack and alienation of social responsibility over time in both co-beneficial and self-beneficial governance cases. From Figure 5, the amount of governance in both co-beneficial and self-beneficial governance increases with time and eventually stabilizes. Self-beneficial governance was 80.4% less than co-beneficial governance. The amount of co-beneficial governance is higher than that of self-beneficial governance, which shows that co-beneficial governance is more conducive to governance of the lack and alienation of social responsibility.

FIGURE 6. Comparison of the influence of parameter $l$ on the amount of governance.

Figures 6 shows the influence of parameter $l$ on the amount of governance in the case of self-beneficial governance and co-beneficial governance. From Figure 6, it can be seen that the optimal trajectory of the amount of governance increases gradually over time and finally reaches stability. In self-beneficial governance, for each additional unit of $l$, the growth rates of the amount of governance accounted for 18.92%, 15.91%, 13.46%, 11.86%, and 10.45% of the original amount of governance, respectively. In co-beneficial governance, for each additional unit of $l$, the growth rate of the amount of governance accounted for 44.86%, 37.39%, 32.05%, 28.04%, and 24.92% of the original amount of governance, respectively. Whether it is self-beneficial governance or co-beneficial governance, although the proportion of the increase is different, the amount of increase is the same. This shows that the higher the maturity of the platform corporate innovation ecosystem, the higher is the amount of governance. Moreover, the growth rate of co-beneficial governance is more elevated, indicating that under the same conditions, compared with self-beneficial governance, co-beneficial governance can produce higher amount of governance and better governance efficiency. The amount of governance rises as the maturity of the innovation ecosystem in which the platform corporation is located increases, suggesting that the more stable the relationship between the subjects of the innovation ecosystem, the more conducive it is to the governance of the lack of social responsibility and alienation of the platform corporation.

FIGURE 7. Comparison of the influence of parameter $\mu$ on the amount of governance.

Figure 7 shows the influence of the parameter on the amount of governance in the case of self-beneficial
FIGURE 8. Comparison of the influence of parameter \( g \) on the amount of governance.

governance and co-beneficial governance. As shown in Figure 6, with the parameter \( \mu \), the optimal trajectory of the amount of governance gradually reaches a specific stable value. In self-beneficial governance, for each additional unit of \( l \), the growth rates of the amount of governance accounted for 50%, 31.82%, 24.14%, 18.92%, and 15.91% of the original amount of governance, respectively. In co-beneficial governance, for each additional unit of \( \mu \), the growth rates of the amount of governance accounted for 112.16%, 74.77%, 56.08%, 44.86%, and 37.39% of the original amount of governance, respectively. Whether it is self-beneficial governance or co-beneficial governance, although the proportion of the increase is different, the amount of increase is the same. The amount of governance increases with an increase in its influence coefficient on governance revenue, indicating that the amount of governance and governance revenue promote each other.

Figures 8 shows the influence of parameter \( g \) on the amount of governance in the case of self-beneficial and co-beneficial governance. From Figure 8, it can be seen that at any moment, the change in the amount of governance increases with an increase in \( g \), which indicates that the change in the government’s effort is more closely related to the increase in the amount of governance. Compared with the increase in other parameters by one unit, the increase in the amount of governance is higher, indicating that government policy is the main factor in the governance of the lack and alienation of platform corporate social responsibility.

It can be seen from Figures 6-8 that compared with self-beneficial governance, co-beneficial governance can achieve a higher amount of governance, and platform corporate social responsibility governance gives priority to co-beneficial governance.

Figure 9 shows the influences of \( k_g \) and \( \delta \) on the amount of governance in the case of co-beneficial governance. As shown in Figure 9, the amount of governance decreases as the decay rate increases, and the amount of governance decreases as the cost coefficients of governance effort for the government increase. This phenomenon shows that when the decay rate of the amount of governance is relatively large, governance is hurt.

C. MODEL VERIFICATION

The SFIC model is a typical model for analyzing collaborative governance problems. The connotation of collaborative governance in this model is the same as that of co-beneficial governance; therefore, the idea of the SFIC model is used to describe co-beneficial governance. Ansell and Gash identified four main variables affecting collaborative governance by analyzing 137 cases: starting conditions, facilitative leadership, collaborative processes, and institutional design. Stakeholders are included in the formal strategy of the government decision-making process [48], the SFIC model is suitable for research on the collaborative governance of platform corporations. The model’s starting conditions and facilitative leadership are used to analyze the co-beneficial governance of the heteronomy of platform corporate social responsibility.

1) INITIAL CONDITIONS

There are some problems with the co-beneficial governance of platform company violations.

1. The rights, resources, and information of each participant are unbalanced.
2. The lack of collaborative motivation.
3. The conflict between the participants.
First, all participants, rights, resources, and information are asymmetric. The government has greater credibility and administrative power, and is advantageous in co-beneficial governance. Bilateral users are subject to funding and power constraints, and are on the passive side of co-beneficial governance.

In terms of interests, bilateral users pursue maximization of economic benefits, and the surplus and shortage of products affect the interests of bilateral users. In contrast, the public expects high-quality, low-priced products, which leads to conflicts of interest.

In terms of co-beneficial motivation, because platform companies master access and resource allocation rules, violations of large-scale platform companies will damage the interests of bilateral users and affect industry development and social benefits.

The difficulty of governance of a single organization increases, prompting a willingness to collaborate in governance.

2) FACILITATIVE LEADERSHIP
In the co-beneficial governance of platform companies’ violations, leadership includes the following parts. First, the government is in a leading position in the governance of platform companies’ violations, and because of the government’s authority, the government needs to pay attention to related stakeholders in the process of co-beneficial governance. In the governance process, the government cooperates with bilateral users and the public to supervise platform corporations. The government is the leader of governance and, at the same time, provides subsidies and incentives to other governmental entities to create a fair and positive market competition environment. Second, because the government cannot control all violations by platform companies, it is difficult to achieve a “perspective” for all violations. Therefore, the leadership of both public and bilateral users is essential. Through coercive force at the national level and the control of bilateral users and the public, to ensure the development of co-beneficial governance

3) PROCESS OF CO-BENEFICIAL GOVERNANCE
In co-beneficial governance, each subject has joint control over the governance process, pursues common interests, and reaches a unified strategic plan when formulating the governance strategy. After achieving the stage results, the three subjects communicate about the governance process and proceed to the next stage of governance. Based on the above analysis, in addition to the first type of self-beneficial governance between bilateral users, the public, and the government, there is another type of system governance strategy, three-party co-beneficial governance. In the process of tripartite co-beneficial governance, the benefits of the three parties are considered. The ultimate goal of co-beneficial governance is to maximize the group’s interests.

4) INSTITUTIONAL DESIGN
According to the comparative analysis of numerical simulation results and the amount of governance and profit obtained, it can be seen that the governance effect of co-beneficial governance on platform corporate social responsibility is better. Based on the numerical analysis results combined with the SFIC model, this section presents the system design of co-beneficial governance.

The institutional design of co-beneficial governance is the design of basic rules and behavioral norms in governance. In co-beneficial governance, including the code of conduct of the governance subject, the government should fully consider the opinions of bilateral users and the public when issuing corresponding systems and regulations to ensure openness of the governance process. In addition, the openness and transparency of the formulation process should be considered. Finally, the governance subject governs the platform corporation in a good system.

Existing research on platform corporate social responsibility and external stakeholders is mostly descriptive. This study used the differential game method to describe the heterogeneity of social responsibility from a dynamic perspective. In addition, this method can be used to study the influence of different parameters on governance and to provide a basis for the strategic choice of governance subjects. Finally, the SFIC model is applied to social responsibility governance to verify the conclusions of the simulation research, which further ensures the accuracy of the conclusions.

V. CONCLUSION
A. MAIN FINDINGS
With the development of advanced technologies such as digital technology and artificial intelligence, a new form of organization, the platform enterprise, has emerged. Platform companies connect bilateral users through their platforms to match supply and demand efficiently. However, at the same time, there is also a lack of alienation from social responsibility, where large platform enterprises have a vast influence and are more likely to use their dominant position to the detriment of other participants. Hence, it is crucial to study the governance of the lack of and alienation from social responsibility. This paper considers the shortcomings of self-centered governance in autonomous governance, using a stakeholder perspective that considers government, the public, and bilateral users as other regulated subjects. It constructs a self-interest governance decision-making model with self-interest as the primary objective and a co-benefit governance decision-making model with the common good as the primary purpose. This paper discusses the optimal strategy of the three actors, the change in the amount of governance over time, the optimal trajectory of total profits, and the impact of relevant parameters on socially responsible governance.

Conclusion 1 is that the degree of governance effort and governance is highest for government, the public, and
bilateral users under co-beneficial governance decisions. Combined with the change in the amount of governance, the amount of governance is more significant in the co-beneficial case than in the self-beneficial case; therefore, co-beneficial governance is a better governance strategy.

Conclusion 2 is that the amount of governance gradually increases with time and finally reaches a specific stable value, and the overall profit gradually decreases with time.

Conclusion 3 is that as the ecosystem’s development stage and the influence of the amount of governance on governance revenue and the impact of the government’s governance effort on the number of governance increases. The amount of governance shows an increasing trend and finally reaches equilibrium. It is clear from the simulation results that an increase in the impact of government governance efforts on the quantity of governance can lead to a rise in the rate of change in the amount of governance. As the decay rate and the cost coefficients of the government increase, the amount of governance tends to decrease, indicating that the higher the cost of governance for the government, the lower the incentive to govern.

B. THEORETICAL AND PRACTICAL IMPLICATIONS

This study examines the governance of platform corporate social responsibility from the perspective of external subjects. It uses the differential game method to express the influence of the governance amount, profit, and related parameters of social responsibility on social responsibility governance through mathematical formulas, which enriches the mathematical description in the theory of social responsibility governance. By establishing the differential game model of the governance subject, the optimal governance form of the platform corporate social responsibility is obtained, that is, co-beneficial governance, which provides a theoretical basis for the governance strategies of the governance subject.

Co-beneficial governance can effectively reduce the lack of social responsibility and alienation of platform corporations, which means that when conducting governance, each subject should be consensus-oriented and give full play to the leadership of each subject. It is vital to ensure that the process is open when developing codes of conduct and basic guidelines, taking complete account of tripartite requirements, and developing transparent, clear, and practical cooperation systems. The more the government pays attention to the governance of social responsibility issues, the greater the amount of governance; the government’s regulations and credibility have a deeper degree of influence on the amount of governance. Therefore, government departments can strengthen legislation to curb social responsibility issues. Although co-beneficial governance can achieve the highest overall profit for the three governance subjects, it is essential to pay attention to the profit of each of the three governance subjects to determine their initiative of the governance subjects. Therefore, there should be a specific mechanism for distributing benefits when co-beneficial governance is conducted. Government departments must adhere to the implementation of macro-controls to provide strong support for corporate development. In addition, in terms of environment, as the ecosystem where the governance subjects are located develops more maturely, the inter-subject dependency relationship becomes more stable, which provides a superior external force in socially responsible governance. From the market environment perspective, the market environment also determines the development of enterprises. Social supervision plays a vital role in the behavior of enterprises. External public opinion can prompt platform enterprises to fulfill their social responsibilities.

C. RESEARCH PROSPECT

This study focuses on the self-beneficial and co-beneficial governance situations in socially responsible governance and studies the amount of governance and profit changes in governance to propose governance strategies, but does not delve into the issue of governance mechanisms in socially responsible governance. In addition, considering the developmental maturity of the ecosystem, future research can further consider using a numerical representation of ecosystem development stages to explore the impact of ecosystem development stages on socially responsible governance.

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