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INCENTIVE MECHANISM OF GOVERNMENT OVERCOMMITMENT IN PPPs BASED ON INVESTORS' FAIRNESS PREFERENCE

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Abstract. In public-private partnerships (PPPs), governments sometimes may not afford the guarantees in full as initially agreed upon due to limited fiscal budgets. Accordingly, government overcommitment can occur. The degree of government overcommitment fulfillment affects not only the incentives provided by governments but also investors' willingness to cooperate and efforts. However, until now, this government overcommitment risk has been ignored during negotiations. Moreover, little attention has been paid to the impact of investors' fairness preference. To this end, this paper constructs an incentive mechanism of government overcommitment based on investors' fairness preference in the horizontal and vertical dimensions. The results show that the optimal strategies of both sides are usually affected by the degree of government overcommitment fulfillment, investors' fairness preference and their willingness to cooperate. Contrary to intuition, the optimal incentive of governments and investors' efforts do not always increase with the decreasing degree of government overcommitment fulfillment, and thus, fairness preferences should be considered. It is not always the case that a higher-level government overcommitment fulfillment is better for themselves. The findings contribute new insights to the incentive mechanism to innovatively work toward creating an effective contract to pay more attention to government overcommitment risk in advance in PPPs.

Keywords: public-private partnerships (PPPs), government overcommitment, incentive mechanism, fairness preference, willingness to cooperate.

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1. Introduction

Public-private partnerships (PPPs) have been widely applied worldwide to relieve the financial burden of local governments and improve public supply (Su et al., 2023; Yuan et al., 2019). In many cases, investors cannot obtain a positive profit solely from its revenue from users, and such revenue may even not be sufficient to cover costs (Feng et al., 2015). More than 90% of the projects in the Management Library require subsidies from local governments in China. Due to risk uncertainty, government guarantees have been an effective means through which to encourage investors to participate in PPPs, by which investors can protect their own revenue in practice (Gao et al., 2015). There are many forms of government guarantees, such as toll charges, road quality and capacity guarantees (Feng et al., 2015), and concession guarantees (Carbonara et al., 2014a; Yan et al., 2019, 2020). Furthermore, these government guarantees are generally stipulated in PPP contracts (Buyukyoran & Gundes, 2018).

Once such a situation occurs, these government guarantees place an increased burden on the public budget. However, the pressure of fiscal expenditure cannot be ignored. For instance, Guizhou Province, China, and the country's State-owned Assets Supervision and Administration Commission recently signed a strategic cooperation framework agreement to support the prevention and resolution of government debt risk, serving as a warning for local governments[1]. Accordingly, governments sometimes may not be able to deliver on their promises in full due to limited fiscal expenditure responsibilities. This phenomenon is a breach of contract known as government overcommitment (Luo et al., 2022). Essentially, government overcommitment focuses on the result that refers to the inability of the government to fulfill its guarantees. Instead, government guarantees are a form of put option (Wang & Liu, 2015). In this regard, this guarantee provision represents a type of risk sharing to reduce the degree of project vulnerability (Wang et al., 2019). Government guarantees may not be fulfilled as a result of limited fiscal expenditure responsibilities. However, previous studies have ignored the impact of government overcommitment on PPP contracts.

In fact, even if investors predict that governments will not be able to fulfill their guarantees, they may participate in PPPs, for example, to expand the market share of or ensure stable employment by enterprises in the case of micro

[1] From https://www.guizhou.gov.cn/home/tt/202304/t20230415_79064344.html

profits. As a result, a reasonable incentive mechanism is critical in the scenario involving government overcommitment (Carbonara et al., 2014b; Wang et al., 2020). Significantly, investors typically have the characteristic of fairness preference when deciding their effort levels (Wang & Liu, 2015; Yan et al., 2020). The fairness perception does not stem from governments not fulfilling their promises but, rather, depends on the obtained project output compared to that for other investment entities and governments. The return utility of investors with the fairness preference is related to the average return level for an equivalent group (Cao et al., 2016). For risk-averse investors, the fairness preference can promote their investment level directly. The higher the fairness preference level is, the more these investors invest during the construction period in PPPs (Gao et al., 2021). Additionally, the optimal amount of compensation provided by governments decreases with the enhancement of investors' fairness preference during the operation period (Gao et al., 2021). Governments can obtain a larger amount of expected revenue by cooperating with those investors with higher fairness preference levels (Wang & Liu, 2015).

In summary, even though many facets of government guarantees have been studied, the impact of government overcommitment on PPP contracts has been largely overlooked in the previous literature. Moreover, the optimal strategies of both governments and investors are affected by investors' fairness preference (Gao et al., 2021). An unfair distribution of benefits may lead to the breakdown of the cooperative relationship between governments and investors and ultimately to the failure of PPPs (Chang & Wang, 2018). Few recent studies have focused on the incentive mechanism of government overcommitment based on investors' fairness preference in PPPs.

Therefore, faced with potential government overcommitment in PPPs, how governments can set up an effective incentive mechanism to attract investor participation urgently needs to be addressed. Moreover, it is particularly important for investors to quantitatively assess this type of risk to determine whether to cooperate with governments during early-stage negotiations. The objective of this paper is to construct an incentive model with government overcommitment to present the optimal strategies for both governments and investors in PPPs that can be sustained by investors. The results help formulate a basis for decision-making by governments and investors in the contractual negotiation phase. Simultaneously, these findings can effectively provide some new insights for investors in considering this risk of government overcommitment in advance to ensure the continuity of PPPs.

The rest of this paper is organized as follows. First, Section 2 presents an overview of the previous research on government guarantees and fairness preferences in PPPs. Next, Section 3 establishes an incentive model of government overcommitment based on investors' fairness preference, followed by the optimal solution. In Section 4, the model results are discussed. Then, a numerical simulation is provided to illustrate the application of this model. Finally, Section 6 concludes the paper by drawing certain conclusions.

2. Literature review

In some cases, to address the risks taken by investors, the provision of guarantees by governments is necessary (Su et al., 2023). There has been a large number of studies conducted on the various factors related to government guarantees in PPPs. Some of these studies have focused on specific types of risk by using an option approach, such as an approach that restricts competition (Liu et al., 2014), a minimum demand guarantee (Wang et al., 2019), a concession period guarantee (Jin et al., 2021), a government minimum revenue guarantee (Quimbayo et al., 2019), and even an early termination mechanism with a government guarantee (He et al., 2022). Moreover, some studies have focused specifically on the issue of the incentive mechanism based on performance-based payment (Li et al., 2022; Su et al., 2023). Differently, Song et al. (2018) proposed a multi-objective Pareto-optimal programming model to investigate the toll, quantity demanded, and social welfare level as well as investors' profits. By their very nature, these government guarantees comprise an important risk-sharing scheme. However, the limited fiscal expenditure responsibilities of local governments have been overlooked. Indeed, governments sometimes may not be able to deliver on their promises in full due to their limited budgets. Accordingly, such a situation leads to a phenomenon called government overcommitment. To this end, faced with possible government overcommitment scenarios in PPPs, how governments can set up effective incentive mechanisms and how investors can rationally choose whether to participate in the negotiation process urgently need to be addressed.

When designing the incentive mechanism for PPPs, an increasing number of scholars have realized the important influence of investors' fairness preference. Independent of how the incentive mechanism is designed by governments, as long as investors perceive unfairness, they prefer to sacrifice their expected profits and reduce their investment levels in projects to pursue a sense of fairness. In particular, the likelihood of investors choosing the optimal investment for a project weakens with strengthening unfairness aversion when investors perceive that the government compensation is at a low level and particularly unfavorable to them, inevitably leading to the emergence of moral hazard (Wu et al., 2019).

Cao et al. (2016) proposed that the return utility of investors with a fairness preference is related to the average return level of equivalent groups. On the one hand, negative utility is generated because investors are jealous of the higher returns of other investors', and on the other hand, blamed negative utility is generated due to higher-than-fair returns. In this scenario, investors' fairness preference brings about only negative effects, and only absolute fairness can enable investors to obtain the greatest expected utility returns. The above authors further suggested that the incentive intensity of governments is not related to the fair wage level available to investors but, rather, to investors' fairness perception. Investors' fairness perception can not only significantly affect the performance of PPPs but also mediate the relationship between risk resharing and investors' behavior (Chen et al., 2021; Du et al., 2018).

Gao et al. (2021) suggested that fairness preference has different effects on different stages of PPPs. For risk-averse investors, during the construction period, fairness preference has a facilitative effect. The stronger investors' level of fairness preference is, the higher their investment level. However, during the operation period, a stronger fairness preference suggests lower-level optimal compensation being provided by governments. Considering the dual identities after intervention in the form of equity, cooperation between governments and investors helps improve the optimal expected returns of the former (He et al., 2020). The results also revealed that when cooperating with investors with a fairness preference, user involvement in PPPs obtains a win-win result for both governments and users. Wang et al. (2021) indicated that the incentive mechanism of governments depends on the market distribution of investors. The degree of incentive intensity provided by governments increases with higher degrees of fairness preference among investors. Investors with a stronger fairness preference tend to engage in opportunistic behaviors more than do those with a weaker fairness preference, but governments prefer to collaborate with the latter due to the costs of regulation (Han et al., 2020). Different from the minimum revenue guarantee, Wang and Liu (2015) showed that governments can obtain a larger amount of expected revenue by cooperating with investors with a higher fairness preference.

In addition, some studies have focused on the fairness relationship between governments and investors. Yan et al. (2019) formulated a model by introducing fairness preference to minimize the utility difference between governments and investors, aiming to ensure the equitable distribution of PPPs. Regardless of whether governments or investors have a fairness preference, the negotiation results always favor the party with such preference, which is not conducive to promoting cooperation; thus, a moderate fairness preference on both sides can contribute to successful negotiations and profit improvements (Wang et al., 2018). Notably, an excessive fairness preference can prevent the maximization of self-interest and social benefits.

From the above literature review, it can be deduced that the growing literature has been developed to analyze government guarantees in PPPs. However, research on the risk of government overcommitment, brought about by local government financial expenditures, is scarce. The impact of investors' fairness preference has also been ignored. To bridge the gaps in the extant literature, this paper incorporates such fairness preference of investors into the incentive mechanism model of government overcommitment in PPPs. Specifically, the research question is how to design an efficient incentive mechanism based on investors' fairness preference to ensure the continuity of PPPs when government overcommitment arises. The formulation is vital for adequate cooperation between governments and investors. Furthermore, this incentive mechanism directly determines whether PPPs can be implemented to a certain extent.

3. Modeling and solution

3.1. Model assumptions

During the operation phase, PPPs are fraught with a great deal of risk, which translates into a great deal of uncertainties in regard to investors' ability to achieve their expected rate of return. When investors' real revenue falls below a certain level (defined here as R_e), they usually have the right, but not the obligation, to require governments to provide subsidies as initially agreed upon (Wang et al., 2020). At this juncture, a put option known as a government guarantee occurs. Such a government guarantee can be understood as the average return that investors can obtain from participating in other projects with the same investment level in the same period (Wang & Gao, 2020). Moreover, the use of subsidies does not mean that governments provide substantial direct funding in the early stage of PPPs (Wang et al., 2019). Instead, government guarantees, typically stipulated in contracts, are an effective incentive method through which to ensure reasonable returns for investors and increase their level of enthusiasm to participate in PPPs. Consequently, local governments have a larger amount of responsibility in terms of fiscal expenditures. However, sometimes, governments cannot completely fulfill their previous commitments, thus leading to government overcommitment.

As "economic individuals" with limited rationality, both behavioral and experimental economists have concluded that humans typically have a fairness preference. Especially in a scenario with government overcommitment in PPPs, investors are not completely rational and compare their revenue with that of others, including other investors and governments as their partners during cooperation. The connotation of fairness preference includes three dimensions in PPPs: distributive fairness, procedural fairness, and interactive fairness (Du et al., 2018). More specifically, investors' fairness preference is reflected in two dimensions: that relative to the principal (the governments) during cooperation, which is a vertical fairness comparison generated by the principal-agent relationship (Wang & Liu, 2015), and that relative to investors participating in other PPPs, which is a horizontal comparison of fairness. Regardless of whether the vertical or horizontal dimension is in effect, investors always want their returns to be higher than those of governments and other investors (Fehr & Schmidt, 1999). In other words, when investors' own revenue is higher than that of governments or other investors, they exhibit pride in their PPPs and, thus, work harder; in contrast, if their returns are lower, then these investors exhibit jealously, which leads to feelings among them of being treated unfairly and reduces the degree of effort they expend. The emotions generated by investors' fairness preference affect their degree of satisfaction with actual revenue (i.e., pride increases investors' satisfaction, and jealousy decreases their satisfaction). Although this satisfaction or preference does not change the actual returns for investors, it does affect their future performance in PPPs. Fairness preference is an inherent attribute of investors, which typically varies across investors. Based on the above analysis, the following assumptions are put forward.

Assumption 1: With government commitment in the negotiation stage as the basis, the prejudgment of the degree of government overcommitment fulfillment is θ and satisfies $0 \le \theta < 1$. The occurrence of government overcommitment is due to limited local fiscal budgets for all PPPs. In practice, the financial situations of different local governments vary, and the degrees of such government overcommitment provided by governments may differ between the two. Even if signed with the same local government, this degree of government overcommitment in a specific project can be distinct from that of other projects.

Assumption 2: In the scenario of government overcommitment in PPPs, the willingness of investors to cooperate with local governments is τ ($0 \le \tau \le 1$). Investors' willingness to cooperate is affected by both macro and micro factors. Under the current policy background and economic development status within a specific country, macro factors have the same degree of influence on all investors and can be regarded as a type of systematic factor affecting investors' willingness to participate in PPPs. The influencing factors at the micro level include the price mechanism (Jin et al., 2020), risk-sharing mechanism (Li & Xue, 2021), and project profit (Wang & Hu, 2019). These factors can all be summarized as the impacts of project revenue risk on investors' willingness to cooperate. In short, in addition to ignoring the established macrolevel systemic factors for PPPs, the willingness of investors to cooperate is related to their own returns; that is, in the scenario in which the local government may overcommit to PPPs, the willingness of investors to cooperate is related to the mechanism for distributing the projects' returns and the degree of government overcommitment fulfillment. The higher the degree of government overcommitment fulfillment is, the stronger the willingness of investors to cooperate; otherwise, the willingness of investors to cooperate is weaker. Investors' willingness to cooperate is a monotonically increasing function of the degree of government overcommitment fulfillment. The relationship between the two can be expressed as follows:

$$\tau = q\theta, \tag{1}$$

where q is the coefficient of the relationship between investors' willingness to cooperate and the degree of government overcommitment fulfillment and $q > 0$. The larger q is, the greater the influence of the degree of government overcommitment fulfillment on investors' willingness to cooperate. The value of the relationship coefficient q is related to investor characteristics. Once investors are identified, the coefficient can also be identified through certain technical means. A certain level of commitment fulfillment from local governments (i.e., $\theta \ne 0$) is the necessary condition for investors' willingness to cooperate (i.e., $\tau \ne 0$).

Assumption 3: In the scenario of government overcommitment in PPPs, there are two types of investor behaviors: mutually beneficial and win-win productive behaviors and self-interested and speculative distributive behaviors (Liu et al., 2016). The levels of productive efforts and of distributive efforts are assumed to be a and e, respectively. The total economic output (R) of PPPs is determined by investors' productive efforts and their willingness to cooperate; the output of the distributive efforts (D) is decided by investors' distributive efforts and their own speculative tendencies (recorded as λ) (Liu et al., 2016; Zhang et al., 2009). Investors' speculative tendencies are usually a stable feature of the investors themselves, and the output of distributive efforts is exclusively collected by investors. Then, the economic output R and the output of distributive efforts D can be constructed as follows (Holmstrom & Milgrom, 1987):

$$R = \tau\left(\eta_1 a + \xi_1\right); \tag{2}$$

$$D = \lambda\left(\eta_2 e + \xi_2\right), \tag{3}$$

where η_1 and η_2 are, respectively, the output coefficient of the economic benefits and speculative behavior, and $\eta_1 > 0$ and $\eta_2 > 0$. ξ_1 and ξ_2 are random variables with a normal distribution, and $\xi_1 \sim N\left(0, \sigma_1^2\right)$ and $\xi_2 \sim N\left(0, \sigma_2^2\right)$. ξ_1 and ξ_2 are independent of one another. The total output of PPPs (expressed as R_{all}) includes two general parts, i.e., economic benefits R and social benefits R_s. Normally, all social benefits are owned by governments. The social benefit coefficient of PPPs is defined as s ($s > 0$); then, the social benefits R_s can be expressed as follows (Gao & Liu, 2019):

$$R_s = s\left(R - D\right) = s\left[\tau\left(\eta_1 a + \xi_1\right) - \lambda\left(\eta_2 e + \xi_2\right)\right]. \tag{4}$$

Assumption 4: In PPPs, the cost coefficient of investors' productive and distributive efforts are b and d, respectively, where $b > 0$ and $d > 0$. Then, the costs of productive efforts $C(a)$ and distributive efforts $C(e)$ can be expressed as follows (Holmstrom & Milgrom, 1987):

$$C\left(a\right) = \frac{1}{2}ba^2; \tag{5}$$

$$C\left(e\right) = \frac{1}{2}de^2. \tag{6}$$

Assumption 5: The distribution ratio of the economic benefits that investors can obtain is β, and $0 \le \beta \le 1$. The proportion of economic benefits that can be obtained by governments is accordingly $1 - \beta$. The returns for investors π_{Inv} and governments π_g in PPPs are as follows:

$$\pi_{Inv} = \beta\left(R - D\right) + D = \beta R + \left(1 - \beta\right)D; \tag{7}$$

$$\pi_g = \left(1 - \beta\right)\left(R - D\right) + R_s = \left(1 - \beta + s\right)\left(R - D\right). \tag{8}$$

When investors' returns in projects π_{Inv} are below the level of the promised government returns R_e, the government guarantee mechanism is activated. The value of the government guarantee option available to investors at this time (denoted by V_{opt}) is as follows:

$$V_{opt} = \theta\left[R_e - \beta\left(R - D\right)\right] = \theta \cdot R_e - \theta\beta\left(R - D\right). \tag{9}$$

Assumption 6: It is assumed that investors' pride and jealousy coefficients are the same and that their vertical fairness preference coefficient relative to governments is δ_1 ($\delta_1 \geq 0$). Therefore, the return perception bias generated by investors' fairness preference in the vertical dimension (expressed as ζ_1) is as follows:

$$\zeta_1 = \delta_1\left[\beta\left(R-D\right)-\left(1-\beta\right)\left(R-D\right)\right] = \delta_1\left(2\beta-1\right)\left(R-D\right). \quad (10)$$

Conversely, it is assumed that the average degree of government overcommitment toward other investors is $\bar{\theta} = \varepsilon\theta$ and satisfies $\varepsilon > 0$. When $0 < \varepsilon < 1$, the average degree of government overcommitment toward other investors is $\theta > \bar{\theta}$; in this case, investors can obtain the government-guaranteed option V_{opt}, resulting in pride; conversely, when $\varepsilon > 1$, that is, $\theta < \bar{\theta}$, investors exhibit jealousy. When $\varepsilon = \varepsilon_0 = 1$, the degrees of government overcommitment fulfillment to all investors are equal, and there is no horizontal return perception bias caused by the unfairness preference. It is assumed that the horizontal fairness preference coefficient of investors relative to other investors is δ_2 ($\delta_2 \geq 0$). Then, the return perception bias generated in the horizontal dimension (recorded as ζ_2) is as follows:

$$\zeta_2 = \delta_2\left(\theta-\bar{\theta}\right)V_{opt} = \delta_2\left(1-\varepsilon\right)\theta\cdot\left[R_e-\beta\left(R-D\right)\right]. \quad (11)$$

Therefore, investors' return perception bias ξ_0 regarding their fairness preference can be expressed as follows:

$$\zeta_0 = \zeta_1+\zeta_2 = \delta_1\left(2\beta-1\right)\left(R-D\right)+\delta_2\left(1-\varepsilon\right)\theta\cdot\left[R_e-\beta\left(R-D\right)\right]. \quad (12)$$

The expected net returns of investors and governments, $E(\zeta_{Inv})$ and $E(\zeta_g)$, respectively, in a government overcommitment scenario for PPPs based on investors' fairness preference are as follows:

$$E\left(\zeta_{Inv}\right) = \left(m\beta-\delta_1\right)\tau\eta_1 a+\left(1+\delta_1-m\beta\right)\lambda\eta_2 e+ \left[1+\delta_2\left(1-\varepsilon\right)\right]\theta R_e-\frac{1}{2}ba^2-\frac{1}{2}de^2; \quad (13)$$

$$E\left(\zeta_g\right) = \left(1-\beta+\theta\beta+s\right)\left(\tau\eta_1 a-\lambda\eta_2 e\right)-\theta R_e, \quad (14)$$

where $m = 1-\theta+2\delta_1+\delta_2\left(\varepsilon-1\right)\theta$.

Assumption 7: As the principal in PPPs, governments are usually risk neutral. In contrast, investors are agents and typically risk averse. The risk aversion coefficient between the two is $\rho > 0$ (Liu et al., 2016). The variance $Var(\zeta_{Inv})$ in the expected net returns of investors is as follows:

$$Var\left(\zeta_{Inv}\right) = \left[\zeta_{Inv}-E\left(\zeta_{Inv}\right)\right]^2 = \left(m\beta-\delta_1\right)^2\tau^2\sigma_1^2+\left(1+\delta_1-m\beta\right)^2\lambda^2\sigma_2^2. \quad (15)$$

In this regard, the certainty utility of both parties U_{Inv} and U_g in PPPs can be expressed as follows:

$$U_{Inv} = E\left(\zeta_{Inv}\right)-\frac{1}{2}\rho\cdot Var\left(\zeta_{Inv}\right) = \left(m\beta-\delta_1\right)\tau\eta_1 a+\left(1+\delta_1-m\beta\right)\lambda\eta_2 e+\left[1+\delta_2\left(1-\varepsilon\right)\right]\theta R_e - \frac{1}{2}ba^2-\frac{1}{2}de^2-\frac{\rho}{2}\left[\left(m\beta-\delta_1\right)^2\tau^2\sigma_1^2+\left(1+\delta_1-m\beta\right)^2\lambda^2\sigma_2^2\right]; \quad (16)$$

$$U_g = E\left(\zeta_g\right) = \left(1-\beta+\theta\beta+s\right)\left(\tau\eta_1 a-\lambda\eta_2 e\right)-\theta R_e. \quad (17)$$

The definitions of these relevant parameters are presented in Table 1.

Table 1. The definitions of the parameters

Symbols	Definitions
R_e	The level of government guarantees
θ	The degree of government overcommitment fulfillment
τ	The willingness of investors to cooperate with local governments
q	The coefficient of the relationship between τ and θ
a	The level of investors' productive efforts
e	The level of investors' distributive efforts
λ	The level of investors' speculative tendencies
R	The economic output
D	The output of distributive efforts
η_1	The output coefficient of the economic benefits
η_2	The output coefficient of the speculative behavior
ξ_1 / ξ_2	Random variables with a normal distribution, and $\xi_1 \sim N\left(0,\sigma_1^2\right)$ and $\xi_2 \sim N\left(0,\sigma_2^2\right)$
R_s	The social benefits of PPPs
$C(a)$	The cost of productive efforts
$C(e)$	The cost of distributive efforts
b	The cost coefficient for productive efforts expended by investors
d	The cost coefficient for distributive efforts expended by investors
β	The distribution ratio of the economic benefits that investors can obtain
V_{opt}	The value of the government guarantee option available to investors
π_{Inv}	The returns of PPPs for investors without fairness preference
π_g	The returns of PPPs for governments
δ_1	The vertical fairness preference coefficient of investors relative to the governments
δ_2	The horizontal fairness preference coefficient of investors relative to other investors
$\bar{\theta}$	The average degree of government overcommitment toward other investors
ε	The coefficient between $\bar{\theta}$ and θ
ζ_1	The return perception bias generated by investors' fairness preference in the vertical dimension
ζ_2	The return perception bias generated by investors' fairness preference in the horizontal dimension
ζ_0	Investors' return perception bias for their fairness preference totally
ρ	The risk aversion coefficient of investors
U_0	The opportunity cost for investors to participate in PPPs
U_{Inv}	The expected utility of investors with fairness preference
U_g	The expected utility of governments

3.2. Model establishment and solution

In PPPs, the partnership between governments and investors is essentially a principal-agent relationship (Gao et al., 2021; Yan et al., 2019). In the game process between the two parties, the utility of governments needs to be maximized first, as governments represent the public's interest; then, investors determine their own optimal strategies based on the incentive provided by governments. It is assumed that the opportunity cost for investors to participate in PPPs is U_0. At this time, the incentive mechanism can be expressed as follows:

$$\underset{\beta}{Max}\ U_g = \left(1-\beta+\theta\beta+s\right)\left(\tau\eta_1 a-\lambda\eta_2 e\right)-\theta R_e; \tag{18}$$

$$s.t.\ U_{Inv} = \left(m\beta-\delta_1\right)\tau\eta_1 a+\left(1+\delta_1-m\beta\right)\lambda\eta_2 e+\left[1+\delta_2\left(1-\varepsilon\right)\right]\theta R_e - \frac{1}{2}ba^2-\frac{1}{2}de^2-\frac{\rho}{2}\left[\left(m\beta-\delta_1\right)^2\tau^2\sigma_1^2+\left(1+\delta_1-m\beta\right)^2\lambda^2\sigma_2^2\right]\ge U_0; \tag{19}$$

$$\underset{a,e}{Max}\ U_{Inv} = \left(m\beta-\delta_1\right)\tau\eta_1 a+\left(1+\delta_1-m\beta\right)\lambda\eta_2 e+\left[1+\delta_2\left(1-\varepsilon\right)\right]\theta R_e - \frac{1}{2}ba^2-\frac{1}{2}de^2-\frac{\rho}{2}\left[\left(m\beta-\delta_1\right)^2\tau^2\sigma_1^2+\left(1+\delta_1-m\beta\right)^2\lambda^2\sigma_2^2\right]. \tag{20}$$

According to the former analyses, the optimal level of productive efforts a^*, optimal distributive efforts e^* and the optimal distribution ratio of investors β^*, respectively, are as follows:

$$a^* = \frac{m\beta-\delta_1}{b}\theta q\eta_1; \tag{21}$$

$$e^* = \frac{1+\delta_1-m\beta}{d}\lambda\eta_2; \tag{22}$$

$$\beta^* = \frac{m_1\cdot q^2\theta^2\eta_1^2 d+\left(m_1-n\right)\cdot\lambda^2\eta_2^2 b+ m\delta_1\cdot q^2\theta^2\sigma_1^2\rho bd+m\left(1+\delta_1\right)\cdot\lambda^2\sigma_2^2\rho bd}{m\left(m-2n\right)\left(q^2\theta^2\eta_1^2 d+\lambda^2\eta_2^2 b\right)+ m^2\left(q^2\theta^2\sigma_1^2\rho bd+\lambda^2\sigma_2^2\rho bd\right)}, \tag{23}$$

where $m = 1-\theta+2\delta_1+\delta_2\left(\varepsilon-1\right)\theta$, $n = 2\delta_1+\delta_2\left(\varepsilon-1\right)\theta$, $m_1 = \left(1+s\right)m-n\delta_1$, and $0 < m-n = 1-\theta \le 1$. When the optimal allocation ratio is 0 < β^* < 1, the optimal decision-making level of investors a^* and e^* can be obtained as follows:

$$a^* = \frac{\left[m_2+\left(1+s\right)n\right]q^2\theta^2\eta_1^2 d+ \left(m_2+sn\right)\lambda^2\eta_2^2 b+\left(1-\theta+n\right)\lambda^2\sigma_2^2\rho bd}{\left[\left(m-2n\right)\left(q^2\theta^2\eta_1^2 d+\lambda^2\eta_2^2 b\right)+ m\left(q^2\theta^2\sigma_1^2\rho bd+\lambda^2\sigma_2^2\rho bd\right)\right]b}\theta q\eta_1; \tag{24}$$

$$e^* = \frac{\left[m_3-\left(s+2\right)n\right]q^2\theta^2\eta_1^2 d+ \left[m_3-\left(s+1\right)n\right]\lambda^2\eta_2^2 b+m\cdot q^2\theta^2\sigma_1^2\rho bd}{\left[\left(m-2n\right)\left(q^2\theta^2\eta_1^2 d+\lambda^2\eta_2^2 b\right)+ m\left(q^2\theta^2\sigma_1^2\rho bd+\lambda^2\sigma_2^2\rho bd\right)\right]d}\lambda\eta_2, \tag{25}$$

where $m_2 = \left(1-\theta\right)\left(1+s-\delta_1\right)$ and $m_3 = \left(1-\theta\right)\left(\delta_1-s\right)$.

4. Model analysis and discussion

In PPPs with government overcommitment from the perspective of investors' fairness preference, the optimal distribution ratio of economic benefits is β^*. When

$$\begin{cases} m_4\cdot q^2\theta^2\eta_1^2 d+\left(m_4+n\right)\lambda^2\eta_2^2 b+m_5\cdot q^2\theta^2\sigma_1^2\rho bd+ \left(m_5-m\right)\lambda^2\sigma_2^2\rho bd\le 0 \\ m\left(m-2n\right)\left(q^2\theta^2\eta_1^2 d+\lambda^2\eta_2^2 b\right)+ m^2\left(q^2\theta^2\sigma_1^2\rho bd+\lambda^2\sigma_2^2\rho bd\right)>0, \end{cases}$$

of which $m_4 = \left(n-\theta+1\right)\left(n-\theta-s\right)+n\left(2\theta-2n+\delta_1-2\right)$, $m_5 = m\left(m-\delta_1\right)$, governments are required to allocate the full economic benefits of PPPs to investors ($\overline{\beta}^* = 1$) to maximize the incentives for investors.

According to Equation (21), even if governments provide the highest level of incentive ($\overline{\beta}^* = 1$), the premise of investors participating in the project and working hard is $m-\delta_1 > 0$; that is, the coefficient ε needs to be $\begin{cases}\varepsilon_1 = 1-\dfrac{1-\theta+\delta_1}{\delta_2\cdot\theta} < 1 \\ \varepsilon > \varepsilon_1\end{cases}$. Different from perceptual cognition, the premise of investors' productive efforts is that the average level of government overcommitment to other investors satisfies $\varepsilon > \varepsilon_1$. At this point, investors' optimal level of productive efforts in PPPs reaches a maximum, $a^*_{\max} = \dfrac{1-\theta+\delta_1+\delta_2\left(\varepsilon-1\right)\theta}{b}\theta q\eta_1$. This optimal level of productive efforts $a^*_{\max}$ is positively correlated with the coefficient of an investor's own fairness preference δ_1 in the vertical dimension of governments, indicating that the higher the degree of vertical fairness preference of investors is, the more productive behavior the investor exerts; i.e., $a^*_{\max}$ increases. However, from the horizontal dimension comparative analysis of investors and other similar investors, the relationship between the optimal level of productive efforts $a^*_{\max}$ and the coefficient of horizontal fairness preference is related to the degree of government overcommitment fulfillment among investors (θ and $\overline{\theta}$); when investors experience a greater deal of government overcommitment fulfillment ($\theta > \overline{\theta}$), i.e., when $\varepsilon_1 \le \varepsilon < 1$, manifesting as a pride-type preference, $a^*_{\max}$ decreases with increasing δ_2. In contrast, when the coefficient satisfies ε > 1, $a^*_{\max}$ increases with δ_2; if the two parties experience equal degrees of government overcommitment ($\theta = \overline{\theta}$), that is, if $\varepsilon = \varepsilon_0 = 1$, then $a^*_{\max}$ is not related to δ_2.

When the incentive intensity provided by governments reaches the highest level ($\overline{\beta}^* = 1$), if the opportunistic behavior of investors is to be completely eliminated, that is, if the optimal level of distributive efforts behavior of investors satisfies $e^*_{\min} \le 0$, then the degree of government overcommitment fulfillment experienced by investors needs to be $\begin{cases}\varepsilon_2 = 1+\dfrac{\theta-\delta_1}{\theta\cdot\delta_2} \\ \varepsilon \ge \varepsilon_2\end{cases}$. When $\theta \le \delta_1$,

$\varepsilon_2 = 1 + \frac{\theta - \delta_1}{\theta \cdot \delta_2} < 1$. In such a scenario, if $\varepsilon_2 < \varepsilon < 1$, then investors exhibit a pride preference to increase their degree of satisfaction with the project and work harder. In contrast, if $\theta > \delta_1$, then $\varepsilon \geq \varepsilon_2 = 1 + \frac{\theta - \delta_1}{\theta \cdot \delta_2} > 1$. In this case, investors experience a lower degree of government overcommitment than do other investors, thus exhibiting jealousy. In short, if investors experience a lower average degree of government overcommitment than do other investors, then they thereby exhibit "jealousy". When investors themselves experience a high degree of government overcommitment but the difference is not significant, then they do not make speculative distributive efforts.

In the scenario of government overcommitment in PPPs, from the perspective of investors' fairness preference, if the government incentive intensity is highest for investors (i.e., if $\beta^* = 1$), then investors' productive behavior is $\varepsilon > \varepsilon_1$, and the condition for the complete elimination of investors' distributive efforts behavior is $\varepsilon \geq \varepsilon_2$. Because the threshold values ε_1 and ε_2 satisfy $\varepsilon_1 < \varepsilon_2$, when $\varepsilon_1 < \varepsilon < \varepsilon_2$, $a^*_{\max} > 0$, and $e^*_{\min} > 0$, investors simultaneously exhibit two behaviors, i.e., productive and speculative efforts in PPPs. When $\varepsilon \geq \varepsilon_2$, $a^*_{\max} > 0$ and $e^*_{\min} \leq 0$, investors do not engage in speculative behavior but choose a certain degree of productive effort behavior. In other words, when governments allocate all the economic benefits of PPPs to investors ($\beta^* = 1$), the threshold value beyond which to completely eliminate investors' speculative behavior is $\varepsilon_2 = 1 - \frac{\delta_1 - \theta}{\theta \cdot \delta_2}$. Such a threshold value, ε_2, is negatively correlated with investors' vertical fairness preference coefficient δ_1 but positively correlated with the horizontal fairness preference coefficient δ_2; that is, the lower the investors' degree of vertical fairness preference coefficient δ_1 is and the greater the horizontal fairness preference coefficient δ_2 is, the larger the threshold value $\varepsilon_2 = 1 + \frac{\theta - \delta_1}{\theta \cdot \delta_2}$. Then, to eliminate the effects of investor speculative behavior, the degree of government overcommitment fulfillment to other investors is higher (ε increases).

4.1. Analysis in the case of fairness preference in the horizontal dimension

In the government overcommitment scenario of PPPs, when the fairness preference toward the government is extremely low, for instance, when $\delta_1 = 0$, investors have fairness preference only in the horizontal dimension. Then, $n_{\zeta_1=0} = \delta_2(\varepsilon - 1)\theta$ and $m_{\zeta_1=0} = 1 - \theta + n_{\zeta_1=0} = 1 - \theta + \delta_2(\varepsilon - 1)\theta$ hold. When the project parameters are satisfied, that is, when

$$\begin{cases} m_4 \cdot q^2\theta^2\eta_1^2 d + (m_4 + n)\lambda^2\eta_2^2 b + m_5 \cdot q^2\theta^2\sigma_1^2\rho bd + \\ (m_5 - m)\lambda^2\sigma_2^2\rho bd > 0 \\ m_1 \cdot q^2\theta^2\eta_1^2 d + (m_1 - n)\lambda^2\eta_2^2 b + m\delta_1 \cdot q^2\theta^2\sigma_1^2\rho bd + \\ m(1+\delta_1)\lambda^2\sigma_2^2\rho bd > 0, \end{cases}$$

the optimal distribution ratio of such economic benefits is $\beta^*_{\zeta_1=0} = \frac{B_2}{B_1} \in (0,1)$, where $B_1 = (1 - \theta + n_{\zeta_1=0})\left[(1 - \theta - n_{\zeta_1=0})(l_1 + l_2) + (1 - \theta + n_{\zeta_1=0})(l_3 + l_4)\right]$ and $B_2 = (1+s)(1 - \theta + n_{\zeta_1=0})(l_1 + l_2) + (1 - \theta + n_{\zeta_1=0})l_4 - n_{\zeta_1=0} \cdot l_2$, $l_1 = q^2\theta^2\eta_1^2 d$, $l_2 = \lambda^2\eta_2^2 b$ $l_3 = q^2\theta^2\sigma_1^2\rho bd$ and $l_4 = \lambda^2\sigma_2^2\rho bd$. When $\left[(1+s)l_1 + s \cdot l_2 + l_4\right]B_1 < 2\left[-n_{\zeta_1=0}(l_1 + l_2) + (n_{\zeta_1=0} + 1 - \theta)(l_3 + l_4)\right]B_2$, $\partial\beta^*_{\zeta_1=0} / \partial n_{\zeta_1=0} < 0$ holds. When overcommitment fulfillment to investors in a project is higher than that to other investors ($\varepsilon_3 < \varepsilon < 1$), $\partial n_{\zeta_1=0} / \partial\delta_2 = (\varepsilon - 1)\theta < 0$. The relationship between the proportion of output distribution available to investors at time $\beta^*_{\zeta_1=0}$ and its own horizontal fairness preference coefficient δ_2 satisfies $\partial\beta^*_{\zeta_1=0} / \partial\delta_2 > 0$, indicating that when investors show a fairness preference only among horizontal investors, the proportion of economic benefits allocated by governments to investors $\beta^*_{\zeta_1=0}$ increases with investors' horizontal fairness preference coefficient δ_2. Conversely, if governments' degree of overcommitment experienced by investors in a project is lower than the average level experienced by other investors ($\varepsilon > 1$), then $\partial\beta^*_{\zeta_1=0} / \partial\delta_2 < 0$. In this regard, the stronger the investors' horizontal fairness preference is (δ_2 is larger), the lower the proportion of the economic benefits allocated by the governments to investors ($\beta^*_{\zeta_1=0}$ is smaller).

When the distribution ratio of economic benefits is $0 < \beta^*_{\zeta_1=0} < 1$, the optimal level of investors' productive efforts is $a^*_{\zeta_1=0} = \frac{m_{\zeta_1=0} \cdot \beta^*_{\zeta_1=0}}{b}\theta q \eta_1$. To make investors work hard (i.e., $a^*_{\zeta_1=0} > 0$ at least), the parameter $m_{\zeta_1=0} = 1 - \theta + \delta_2(\varepsilon - 1)\theta > 0$ should be satisfied. At this time, governments are required to distribute the average government overcommitment to other investors participating in PPPs; that is, $\varepsilon > \varepsilon_3 = 1 - \frac{1-\theta}{\delta_2 \cdot \theta}$. Then the optimal level of productive efforts is

$$a^*_{\zeta_1=0} = \frac{(1+s)(1 - \theta + n_{\zeta_1=0})(l_1 + l_2) + (1 - \theta + n_{\zeta_1=0})l_4 - n_{\zeta_1=0} \cdot l_2}{\left[(1 - \theta - n_{\zeta_1=0})(l_1 + l_2) + (1 - \theta + n_{\zeta_1=0})(l_3 + l_4)\right]b}\theta q \eta_1.$$

When the horizontal fairness preference coefficient δ_2 satisfies $\left[(1+s)l_1 + s \cdot l_2 + l_4\right]B_3 > \left[(l_3 + l_4) - (l_1 + l_2)\right]B_2$, $\partial a^*_{\zeta_1=0} / \partial n_{\zeta_1=0} > 0$, where $B_3 = (1 - \theta - n_{\zeta_1=0})(l_1 + l_2) + (1 - \theta + n_{\zeta_1=0})(l_3 + l_4)$. When $\varepsilon_3 < \varepsilon < 1$, $\partial n_{\zeta_1=0} / \partial\delta_2 = (\varepsilon - 1)\theta < 0$, indicating that the higher the investors' degree of fairness preference (δ_2 is larger), the weaker the optimal productive efforts of the investors under the conditions of the other parameters being unchanged ($a^*_{\zeta_1=0}$ is smaller). When governments offer the maximum incentive strength ($\beta^*_{\zeta_1=0} = 1$), the level of productive efforts is at its highest $\left(a^*_{\zeta_1=0}\right)_{\max} = \frac{1 - \theta + \delta_2(\varepsilon - 1)\theta}{b}\theta q \eta_1$. At this point, the relationship between investors' level of productive efforts $\left(a^*_{\zeta_1=0}\right)_{\max}$ and the horizontal fairness preference coefficient δ_2 is related to the coefficient ε. When $\varepsilon_3 < \varepsilon < 1$, investors show a pride preference. Then, the higher the degree of horizontal fairness preference is (δ_2 is larger), the lower investors' level of productive efforts. Conversely, if $\varepsilon > 1 > \varepsilon_3$, then investors exhibit jealousy. There is a higher degree of horizontal fairness preference and jealousy (δ_2 is larger), and there is an increase in energy expended into productive efforts $\left(a^*_{\zeta_1=0}\right)_{\max}$ in such a scenario.

In such a scenario of investors' horizontal fairness preference, the optimal level of distributive efforts is

$$e^*_{\zeta_1=0} = \frac{\left[-s(1-\theta)-(s+2)n_{\zeta_1=0}\right](l_1+l_2)+\left(1-\theta+n_{\zeta_1=0}\right)l_3+n_{\zeta_1=0}\cdot l_2}{\left[\left(1-\theta-n_{\zeta_1=0}\right)(l_1+l_2)+\left(1-\theta+n_{\zeta_1=0}\right)(l_3+l_4)\right]d}\lambda\eta_2.$$

Whether investors speculate depends on the value of

$$\frac{\left[-s(1-\theta)-(s+2)n_{\zeta_1=0}\right](l_1+l_2)+\left(1-\theta+n_{\zeta_1=0}\right)l_3+n_{\zeta_1=0}\cdot l_2}{B_3}.$$

When investors experience higher levels of government overcommitment, i.e., when $\varepsilon_3 < \varepsilon \le 1$, $n_{\zeta_1=0} = \delta_2(\varepsilon-1)\theta \le 0$; then, $B_3 > 0$ must be established. At this moment, whether investors take self-interested distributive efforts is determined mainly by B_4 and B_5, where $B_4 = \left[(s+2)(l_1+l_2)-(l_2+l_3)\right]n_{\zeta_1=0}$ and $B_5 = (1-\theta)\left[l_3-(l_1+l_2)s\right]$. When $B_4 < 0$, it means that $B_5 > 0$. If $\varepsilon_4 < \varepsilon \le 1$, then the level of speculative behavior remains the optimal strategy choice, where $\varepsilon_3 < \varepsilon_4 = 1-\frac{(1-\theta)\left[l_3-(l_1+l_2)s\right]}{\left[(l_2+l_3)-(s+2)(l_1+l_2)\right]\delta_2\theta} < 1$. When $B_4 > 0$ and $B_5 < 0$, if $\varepsilon_3 < \varepsilon < \varepsilon_5$, of which $\varepsilon_3 < \varepsilon_5 = 1-\frac{(1-\theta)\left[(l_1+l_2)s-l_3\right]}{\left[(s+2)(l_1+l_2)-(l_2+l_3)\right]\delta_2\theta} < 1$, then $e^*_{\zeta_1=0} > 0$. Provided $B_4 > 0$ and $B_5 > 0$ in $\varepsilon_3 < \varepsilon \le 1$, $e^*_{\zeta_1=0} > 0$ always holds, suggesting that investors inevitably exert distributive efforts. The speculative distributive efforts of investors ($e^*_{4|\zeta_1=0} > 0$) are shown in Table 2.

In this case, if $\left[-(s+2)(l_1+l_2)+l_2+l_3\right]B_3 > (l_3+l_4-l_1-l_2)B_7$ holds, then $\partial e^*_{\zeta_1=0}/\partial n_{\zeta_1=0} > 0$, where $B_7 = \left[-s(1-\theta)-(s+2)n_{\zeta_1=0}\right](l_1+l_2)+\left(1-\theta+n_{\zeta_1=0}\right)l_3+n_{\zeta_1=0}\cdot l_2$. When $\varepsilon_3 < \varepsilon < 1$, then $\partial n_{\zeta_1=0}/\partial\delta_2 = (\varepsilon-1)\theta < 0$; therefore, $\partial e^*_{\zeta_1=0}/\partial\delta_2 < 0$, signifying that the higher the degree of horizontal fairness preference of investors is (δ_2 is larger), under the conditions of the other project parameters being unchanged, the lower the level of investors' optimal distributive efforts ($e^*_{\zeta_1=0}$ is smaller). When governments provide the maximum incentive ($\overline{\beta^*_{\zeta_1=0}} = 1$), the distributive efforts of investors are suppressed to the maximum extent and reach the lowest level $\left(e^*_{\zeta_1=0}\right)_{\min} = \frac{1-\delta_2(\varepsilon-1)}{d}\theta\lambda\eta_2$. If the degree of government overcommitment fulfillment obtained by investors is lower than that of other investors to a certain level, then a jealousy preference emerges; that is, when the coefficient $\varepsilon \ge \frac{1}{\delta_2}+1$, $\left(e^*_{\zeta_1=0}\right)_{\min} \le 0$, and the speculative distributive efforts of investors in the project are completely eliminated.

Table 2. Different scenarios of cooperation between governments with investors with horizontal fairness preference

Series number	Fairness preference	Scenario classification	Parameter situation	Coefficient ε
1	pride preference $\varepsilon_3 < \varepsilon \le 1$	$n_{\zeta_1=0} \le 0$	$B_4 < 0$	$\varepsilon_4 < \varepsilon \le 1$
			$B_4 > 0$, $B_5 < 0$	$\varepsilon_3 < \varepsilon < \varepsilon_5$
			$B_4 > 0$, $B_5 > 0$	$\varepsilon_3 < \varepsilon \le 1$
2	jealous preference $\varepsilon > 1 > \varepsilon_3$	$n_{\zeta_1=0} > 0$	$B_6 \ge 0$, $B_4 > 0$, $B_5 > 0$	$1 < \varepsilon < \varepsilon_7$
			$B_6 < 0$, $B_4 > 0$, $B_5 > 0$	$\begin{cases}1<\varepsilon<\varepsilon_6\\1<\varepsilon<\varepsilon_7\end{cases}$
			$B_6 \ge 0$, $B_4 < 0$, $B_5 > 0$	$\varepsilon_3 < \varepsilon \le 1$
			$B_6 < 0$, $B_4 < 0$, $B_5 > 0$	$1 < \varepsilon < \varepsilon_6$
			$B_6 < 0$, $B_4 > 0$, $B_5 > 0$	$\varepsilon > \varepsilon_6$
			$B_6 < 0$, $B_4 > 0$, $B_5 > 0$	$\begin{cases}\varepsilon>\varepsilon_6\\\varepsilon>\varepsilon_7\end{cases}$

Note: $\varepsilon_6 = 1+\frac{(1-\theta)(l_1+l_2+l_3+l_4)}{(l_1+l_2-l_3-l_4)\delta_2\theta} > 1$, $\varepsilon_7 = 1+\frac{(1-\theta)\left[l_3-(l_1+l_2)s\right]}{\left[(s+2)(l_1+l_2)-(l_2+l_3)\right]\delta_2\theta}$.

4.2. Analysis in the case of fairness preference in the vertical dimension

Due to the limited general public budget of local governments, if governments treat all investors participating in PPPs fairly, then all investors can obtain exactly the same level of government guarantees and $\bar{\theta} = \theta$, regardless of the degree of investors' horizontal fairness preference; in such a case, investors do not exhibit any return perception bias. Conversely, even if the fulfillment degree of government overcommitment obtained by all investors is not completely consistent, when investors' horizontal fairness preference is extremely weak and negligible (for example, when $\delta_2 = 0$), there is still no return perception bias in the horizontal dimension of investors; that is, $\zeta_2 = \delta_2\left(\theta - \bar{\theta}\right)V_{opt} = 0$. Then, $n_{\zeta_2=0} = 2\delta_1$, $m_{\zeta_2=0} = 1-\theta+n_{\zeta_2=0} = 1-\theta+2\delta_1$, and $m_{1|\zeta_2=0} = \left(1+s\right)m_{\zeta_2=0} - 2\delta_1^2$. At this time, the optimal distribution ratio of economic benefits is

$$\beta^*_{\zeta_2=0} = \frac{\left[\left(1+s\right)m_{\zeta_2=0} - n_{\zeta_2=0}\cdot\delta_1\right]\left(l_1+l_2\right) + m_{\zeta_2=0}\cdot\delta_1\left(l_3+l_4\right) + m_{\zeta_2=0}\cdot l_4 - n_{\zeta_2=0}\cdot l_2}{m_{\zeta_2=0}\left[\left(1-\theta-n_{\zeta_2=0}\right)\left(l_1+l_2\right) + m_{\zeta_2=0}\cdot\left(l_3+l_4\right)\right]}.$$

When $\beta^*_{\zeta_2=0} \in \left(0,1\right)$, the relationship between $\beta^*_{\zeta_2=0}$ and δ_1 is affected by other parameters. Supposing that $B_9\cdot B_8^{'} > B_9^{'}\cdot B_8$, then $\partial\beta^*_{\zeta_2=0}/\partial\delta_1 > 0$, and the higher degree of vertical fairness preference, the more economic benefits governments should allocate to investors, where $B_8 = \left[\left(1+s\right)m_{\zeta_2=0} - n_{\zeta_2=0}\delta_1\right]\left(l_1+l_2\right) + m_{\zeta_2=0}\delta_1\left(l_3+l_4\right) + l_4 m_{\zeta_2=0} - l_2 n_{\zeta_2=0}$, $B_9 = m_{\zeta_2=0}\left[\left(1-\theta-n_{\zeta_2=0}\right)\left(l_1+l_2\right) + m_{\zeta_2=0}\left(l_3+l_4\right)\right]$, $B_8^{'} = 2\left(1+s-2\delta_1\right)\left(l_1+l_2\right) + \left(1-\theta+4\delta_1\right)\left(l_3+l_4\right) + 2\left(l_4-l_2\right)$, and $B_9^{'} = -8\delta_1\left(l_1+l_2\right) + 4\left(2\delta_1+1-\theta\right)\left(l_3+l_4\right)$.

When $\beta^*_{\zeta_2=0} \in \left(0,1\right)$, the optimal level of productive efforts is $a^*_{\zeta_2=0} = \frac{m_{\zeta_2=0}\cdot\beta^*_{\zeta_2=0} - \delta_1}{b}\theta q\eta_1$. For investors to cooperate with governments and participate in PPPs, such optimal efforts must meet the condition that $a^*_{\zeta_2=0} = \frac{B_{10}}{B_{11}\cdot b}\theta q\eta_1 > 0$, of which $B_{10} \times B_{11} > 0$ must be obtained, where $B_{10} = \left[\left(1+s\right)\left(1-\theta+n_{\zeta_2=0}\right) - \left(1-\theta\right)\delta_1\right]\left(l_1+l_2\right) + \left(1-\theta+n_{\zeta_2=0}\right)l_4 - n_{\zeta_2=0}l_2$ and $B_{11} = \left(1-\theta-n_{\zeta_2=0}\right)\left(l_1+l_2\right) + \left(1-\theta+n_{\zeta_2=0}\right)\cdot\left(l_3+l_4\right)$. When $2\left(l_2-l_4\right) > \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right)$, regardless of the level of investors' fairness preference in the vertical dimension (i.e., vertical fairness preference coefficient $\delta_1 > 0$), $B_{10} > 0$ holds. In contrast, to establish the coefficient $B_{10} > 0$, δ_1 should be $0 < \delta_1 < \frac{\left(1+s\right)\left(1-\theta\right)\left(l_1+l_2\right) + \left(1-\theta\right)l_4}{2\left(l_2-l_4\right) - \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right)}$. In contrast, when $l_3 + l_4 \ge l_1 + l_2$, $B_{11} > 0$; on the contrary, suppose that $l_3 + l_4 < l_1 + l_2$, only when the value of investors' vertical fairness preference is $0 < \delta_1 < \frac{\left(1-\theta\right)\left(l_1+l_2+l_3+l_4\right)}{2\left(l_1+l_2-l_3-l_4\right)}$

Table 3. Different scenarios of cooperation between governments with investors with vertical fairness preference

Serial number	Project parameter range	Value range of δ_1	Judgment condition	$a^*_{\zeta_2=0}$
1	$\begin{cases} 2\left(l_2-l_4\right) \le \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right) \\ l_3+l_4 \ge l_1+l_2 \end{cases}$	$\delta_1 > 0$	$B_{10} > 0$ $B_{11} > 0$	$a^*_{\zeta_2=0} > 0$
2	$\begin{cases} 2\left(l_2-l_4\right) > \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right) \\ l_3+l_4 \ge l_1+l_2 \end{cases}$	$0 < \delta_1 < \delta_{11}$	$B_{10} > 0$ $B_{11} > 0$	$a^*_{\zeta_2=0} > 0$
3	$\begin{cases} 2\left(l_2-l_4\right) \le \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right) \\ l_3+l_4 < l_1+l_2 \end{cases}$	$0 < \delta_1 < \delta_{12}$	$B_{10} > 0$ $B_{11} > 0$	$a^*_{\zeta_2=0} > 0$
4	$\begin{cases} 2\left(l_2-l_4\right) > \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right) \\ l_3+l_4 < l_1+l_2 \end{cases}$	$\begin{cases} 0 < \delta_1 < \delta_{11} \\ 0 < \delta_1 < \delta_{12} \end{cases}$	$B_{10} > 0$ $B_{11} > 0$	$a^*_{\zeta_2=0} > 0$
5	$\begin{cases} 2\left(l_2-l_4\right) > \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right) \\ l_3+l_4 < l_1+l_2 \end{cases}$	$\begin{cases} \delta_1 > \delta_{11} > 0 \\ \delta_1 > \delta_{12} > 0 \end{cases}$	$B_{10} < 0$ $B_{11} < 0$	$a^*_{\zeta_2=0} > 0$

Note: $\delta_{11} = \frac{\left(1+s\right)\left(1-\theta\right)\left(l_1+l_2\right) + \left(1-\theta\right)l_4}{2\left(l_2-l_4\right) - \left(2s+\theta+1\right)\cdot\left(l_1+l_2\right)}$ and $\delta_{12} = \frac{\left(1-\theta\right)\left(l_1+l_2+l_3+l_4\right)}{2\left(l_1+l_2-l_3-l_4\right)}$.

can the coefficient $B_{11} > 0$. The preconditions for investors to cooperate with governments and strive to participate in PPPs are summarized in Table 3.

When governments provide investors with the highest-level incentive intensity ($\overline{\beta^*_{\zeta_2=0}} = 1$), investors' corresponding optimal productive efforts is $\left(a^*_{\zeta_2=0}\right)_{\max} = \frac{1-\theta+\delta_1}{b}\theta q\eta_1 > 0$, and investors are bound to make productive efforts in PPPs. The optimal level of productive efforts $\left(a^*_{\zeta_2=0}\right)_{\max}$ increases gradually with investors' own vertical fairness preference coefficient δ_1; additionally, the relationship between investors' optimal level of productive efforts $\left(a^*_{\zeta_2=0}\right)_{\max}$ and degree of government overcommitment θ is also related to investors' vertical fairness preference coefficient δ_1. When $0 < \delta_1 < 1$, investors' optimal level of productive efforts $\left(a^*_{\zeta_2=0}\right)_{\max}$ increases with an increasing degree of government overcommitment θ ($0 < \theta < \frac{1+\delta_1}{2}$) and then decreases with an increasing degree of government overcommitment θ ($\frac{1+\delta_1}{2} < \theta < 1$). When $\theta_0 = \frac{1+\delta_1}{2}$, investors' optimal productive efforts peak, and investors' optimal efforts $\left(a^*_{\zeta_2=0}\right)_{\max}$ and government overcommitment θ exhibit a quadratic top-down relationship; when $\delta_1 \geq 1$, due to $\theta_0 = \frac{1+\delta_1}{2} > 1$, the optimal level of investors' productive efforts $\left(a^*_{\zeta_2=0}\right)_{\max}$ increases with an increasing degree of government overcommitment θ, showing a gradually increasing relationship, but the growth rate gradually decreases.

Similarly, the optimal level of investors' distributive efforts is $e^*_{\zeta_2=0} = \frac{B_{12}}{B_{11}\cdot d}\lambda\eta_2$, of which $B_{12} = \left[-s(1-\theta)-(\theta+2s+3)\delta_1\right](l_1+l_2)+(1-\theta+2\delta_1)l_3-2\delta_1\cdot l_2$. When $B_{12} \times B_{11} > 0$, investors' optimal distributive efforts, $e^*_{\zeta_2=0} > 0$, are inevitably unpredictable. Combined with $B_{11} > 0$ mentioned above, the scenarios of speculative behaviors are summarized in Table 4.

When the parameters satisfy $\left[2(l_2+l_3)-(\theta+2s+3)(l_1+l_2)\right]B_3 > 2(l_3+l_4-l_1-l_2)B_{10}$, $\partial e^*_{\zeta_2=0}/\partial\delta_1 > 0$, indicating that the higher the degree of investors' fairness preference in the vertical dimension is (δ_1 is

Table 4. Different scenarios of investors' distributive efforts with vertical fairness preference

Serial number	Project parameter range	Value range of δ_1	Judgment condition	$e^*_{\zeta_2=0}$
1	$\begin{cases}(\theta+2s+3)(l_1+l_2) < 2(l_2+l_3)\\ l_3+l_4 \geq l_1+l_2\end{cases}$	$\delta_1 > 0$	$B_{12} > 0$ $B_{11} > 0$	$e^*_{\zeta_2=0} > 0$
2	$\begin{cases}(\theta+2s+3)(l_1+l_2) > 2(l_2+l_3)\\ l_3-(l_1+l_2)s > 0\\ l_3+l_4 \geq l_1+l_2\end{cases}$	$0 < \delta_1 < \delta_{13}$	$B_{12} > 0$ $B_{11} > 0$	$e^*_{\zeta_2=0} > 0$
3	$\begin{cases}(\theta+2s+3)(l_1+l_2) < 2(l_2+l_3)\\ l_3+l_4 < l_1+l_2\end{cases}$	$0 < \delta_1 < \delta_{12}$	$B_{12} > 0$ $B_{11} > 0$	$e^*_{\zeta_2=0} > 0$
4	$\begin{cases}(\theta+2s+3)(l_1+l_2) > 2(l_2+l_3)\\ l_3-(l_1+l_2)s > 0\\ l_3+l_4 < l_1+l_2\end{cases}$	$\begin{cases}0 < \delta_1 < \delta_{13}\\ 0 < \delta_1 < \delta_{12}\end{cases}$	$B_{12} > 0$ $B_{11} > 0$	$e^*_{\zeta_2=0} > 0$
5	$\begin{cases}(\theta+2s+3)(l_1+l_2) > 2(l_2+l_3)\\ l_3-(l_1+l_2)s < 0\\ l_3+l_4 < l_1+l_2\end{cases}$	$\delta_1 > \delta_{12} > 0$	$B_{12} < 0$ $B_{11} < 0$	$e^*_{\zeta_2=0} > 0$
6	$\begin{cases}(\theta+2s+3)(l_1+l_2) > 2(l_2+l_3)\\ l_3-(l_1+l_2)s > 0\\ l_3+l_4 < l_1+l_2\end{cases}$	$\begin{cases}\delta_1 > \delta_{13} > 0\\ \delta_1 > \delta_{12} > 0\end{cases}$	$B_{12} < 0$ $B_{11} < 0$	$e^*_{\zeta_2=0} > 0$

Note: $\delta_{13} = \frac{(1-\theta)\left[l_3-(l_1+l_2)s\right]}{(\theta+2s+3)(l_1+l_2)-2(l_2+l_3)}$.

larger), the higher the level of investors' optimal distributive efforts $e^*_{\zeta_2=0}$, that is, the more speculative the behavior engaged in by investors in PPPs. If $\left[2\left(l_2+l_3\right)-\left(\theta+2s+3\right)\left(l_1+l_2\right)\right]\cdot B_{11}<2\left(l_3+l_4-l_1-l_2\right)\cdot B_{12}$, then $\partial e^*_{\zeta_2=0}/\partial\delta_1<0$. Within a certain range of the vertical fairness preference coefficient δ_1, investors' distributive efforts decrease with the increase in their own vertical fairness preference. Based on the above logical analysis, investors do not engage in speculative behaviors (that is, the optimal level of distributive efforts $e^*_{\zeta_2=0}\le 0$), as shown in Table 5.

If the optimal strategy of governments is $\overline{\beta^*_{\zeta_2=0}}=1$, then when investors can obtain the highest-level incentive intensity, the corresponding optimal distributive efforts are at the lowest level; i.e., $\left(e^*_{\zeta_2=0}\right)_{\min}=\frac{\theta-\delta_1}{d}\lambda\eta_2$. At this point, from a mathematical point of view, as long as the degree of government overcommitment fulfillment θ obtained by investors exceeds the value of investors' own vertical fairness preference coefficient δ_1, that is, satisfies $\theta-\delta_1>0$, then investors' optimal distributive efforts in PPPs are $\left(e^*_{\zeta_2=0}\right)_{\min}>0$. This finding suggests that investors are bound to exhibit speculative behavior. In other words, when investors have a preference only for vertical fairness in the government overcommitment scenario, if governments allocate all economic benefits to investors and intend to completely eliminate investors' speculative behavior, then the governments are required to accurately analyze the vertical fairness preference of investors δ_1, ensuring that the degree of overcommitment by the governments to investors is relatively low and satisfies $\theta<\delta_1$.

4.3. Comparative analysis before and after investors exhibit a fairness preference

In the scenario of government overcommitment for PPP projects, under the completely rational state ($\delta_1=\delta_2=0$), investors can obtain economic benefits as a proportion of $\beta^*_2=\frac{\left(1+s\right)\left(l_1+l_2\right)+l_4}{\left(1-\theta\right)\left(l_1+l_2+l_3+l_4\right)}$; if this ratio satisfies $\beta^*_2\in\left(0,1\right)$, then the optimal productive and distributive effort levels are, respectively, $a^*_2=\frac{\left(1+s\right)\left(l_1+l_2\right)+l_4}{\left(l_1+l_2+l_3+l_4\right)b}\theta q\eta_1$ and $e^*_2=\frac{l_3-\left(l_1+l_2\right)s}{\left(l_1+l_2+l_3+l_4\right)d}\lambda\eta_2$. The difference in the

Table 5. Different scenarios of investors' no speculative behavior with vertical fairness preference

Serial number	Project parameter range	Value range of δ_1	Judgment condition	$e^*_{\zeta_2=0}$
1	$l_3-\left(l_1+l_2\right)s=0$	$\delta_1>0$	$B_{12}=0$	$e^*_{\zeta_2=0}=0$
2	$\begin{cases}\left(\theta+2s+3\right)\left(l_1+l_2\right)>2\left(l_2+l_3\right)\\ l_3-\left(l_1+l_2\right)s<0\\ l_3+l_4\ge l_1+l_2\end{cases}$	$\delta_1>0$	$B_{12}<0$ $B_{11}>0$	$e^*_{\zeta_2=0}<0$
3	$\begin{cases}\left(\theta+2s+3\right)\left(l_1+l_2\right)>2\left(l_2+l_3\right)\\ l_3-\left(l_1+l_2\right)s<0\\ l_3+l_4<l_1+l_2\end{cases}$	$0<\delta_1<\delta_{12}$	$B_{12}<0$ $B_{11}>0$	$e^*_{\zeta_2=0}<0$
4	$\begin{cases}\left(\theta+2s+3\right)\left(l_1+l_2\right)>2\left(l_2+l_3\right)\\ l_3-\left(l_1+l_2\right)s>0\\ l_3+l_4\ge l_1+l_2\end{cases}$	$\delta_1>\delta_{13}>0$	$B_{12}<0$ $B_{11}>0$	$e^*_{\zeta_2=0}<0$
5	$\begin{cases}\left(\theta+2s+3\right)\left(l_1+l_2\right)>2\left(l_2+l_3\right)\\ l_3-\left(l_1+l_2\right)s>0\\ l_3+l_4<l_1+l_2\end{cases}$	$\begin{cases}0<\delta_1<\delta_{12}\\ \delta_1>\delta_{13}>0\end{cases}$	$B_{12}<0$ $B_{11}>0$	$e^*_{\zeta_2=0}<0$
6	$\begin{cases}\left(\theta+2s+3\right)\left(l_1+l_2\right)<2\left(l_2+l_3\right)\\ l_3-\left(l_1+l_2\right)s>0\\ l_3+l_4<l_1+l_2\end{cases}$	$\delta_1>\delta_{12}>0$	$B_{12}>0$ $B_{11}<0$	$e^*_{\zeta_2=0}<0$
7	$\begin{cases}\left(\theta+2s+3\right)\left(l_1+l_2\right)>2\left(l_2+l_3\right)\\ l_3-\left(l_1+l_2\right)s>0\\ l_3+l_4<l_1+l_2\end{cases}$	$\begin{cases}\delta_1>\delta_{13}>0\\ \delta_1>\delta_{12}>0\end{cases}$	$B_{12}>0$ $B_{11}<0$	$e^*_{\zeta_2=0}<0$

distribution proportions given to investors by governments is compared before and after investors exhibit a fairness preference, $\Delta\beta$, is as follows:

$$\Delta\beta = \beta^* - \beta_2^* = \frac{(l_1 + l_2 - l_3 - l_4)B_{30} - (1-\theta)(l_1 + l_2 + l_3 + l_4)B_{31}}{B_{29} \cdot m(1-\theta)(l_1 + l_2 + l_3 + l_4)}, \quad (26)$$

where $B_{13} = (1-\theta)(l_1 + l_2 + l_3 + l_4) + n(l_3 + l_4 - l_1 - l_2)$, $B_{14} = [(1+s)(l_1 + l_2) + l_4]mn$ and $B_{15} = m\delta_1(l_3 + l_4) - n\delta_1(l_1 + l_2) - n \cdot l_2$. When parameter $(l_1 + l_2 - l_3 - l_4)B_{14} = (1-\theta)(l_1 + l_2 + l_3 + l_4)B_{15}$ is established, regardless of whether investors exhibit a fairness preference, the distribution proportions of the economic benefits of PPPs to investors by governments are the same. When $[(l_1 + l_2 - l_3 - l_4)B_{14} - (1-\theta)(l_1 + l_2 + l_3 + l_4)B_{15}]B_{13} \cdot m > 0$ is met, $\Delta\beta = \beta^* - \beta_2^* > 0$, and at this time, governments should give a higher proportion of the economic benefit outputs of PPPs to investors with a fairness preference; conversely, the optimal strategy for governments is to allocate a greater proportion of the economic benefit outputs of PPPs to completely rational investors.

If the optimal strategy for governments is to share the economic benefit outputs of PPPs with the investors, that is, if $\beta^* \in (0,1)$ and $\beta_2^* \in (0,1)$ are both satisfied, then the difference in the optimal decision level of investors before and after exhibiting a fairness preference Δa and Δe are as follows:

$$\Delta a = a^* - a_2^* = \frac{B_{32} - B_{33}}{B_{29} \cdot b}\theta q \eta_1; \quad (27)$$

$$\Delta e = e^* - e_2^* = \frac{B_{34} + B_{35}}{B_{29} \cdot d}\lambda \eta_2, \quad (28)$$

where $B_{16} = [(1+s)(l_1 + l_2) + l_4](l_1 + l_2)$, $B_{17} = [(1-\theta)\delta_1(l_1 + l_2) + n \cdot l_2](l_1 + l_2 + l_3 + l_4)$, $B_{18} = \{[(1-\theta)\delta_1 - 2n](l_1 + l_2) - n \cdot l_2\}$, and $B_{19} = 2n(l_1 + l_2)[l_3 - (l_1 + l_2)s]$. As shown in Equation (27), when each parameter in the PPP satisfies $B_{16} = B_{17}$, investors' fairness preference does not affect their optimal productive effort levels; that is, $a^* = a_2^*$ is established. When the parameters of the project satisfy $(B_{16} - B_{17})B_{13} > 0$, at this time, $\Delta a = a^* - a_2^* > 0$, indicating that investors with a certain degree of fairness preference are willing to choose a higher level of productive effort behavior ($a^* > a_2^*$) to maximize their own benefits. In contrast, if $(B_{16} - B_{17})B_{13} < 0$ is established, then the productive effort level of investors in a completely rational situation increases ($a^* < a_2^*$); in other words, a certain degree of fairness preference prevents investors from investing in productive effort behaviors.

Similarly, Equation (28) shows that when each parameter of a PPP satisfies the condition $B_{18} + B_{19} = 0$, $e^* = e_2^*$ is established, which means that the speculative levels of investors in a completely rational state and when they have certain fairness preferences are not different. When the parameter satisfies $(B_{18} + B_{19})B_{13} < 0$ and $\Delta e = e^* - e_2^* < 0$, at this time, a certain degree of fairness preference among investors can effectively inhibit more speculative behavior; that is, $e_4^* < e_2^*$ is established. Conversely, when the project parameters satisfy the condition $(B_{18} + B_{19})B_{13} > 0$, indicating that $\Delta e = e^* - e_2^* > 0$, that is, under the situation that other parameters remain unchanged, the fairness preference characteristic causes investors to implement a greater degree of speculative behavior ($e^* > e_2^*$).

To motivate investors to participate in PPPs to the maximum extent, when governments provide the strongest incentive, i.e., when $\overline{\beta^*} = \overline{\beta_2^*} = 1$, the optimal productive effort level when investors are completely rational is $(a_2^*)_{max} = \frac{1-\theta}{b}\theta q \eta_1$, and the optimal level of distributive effort behavior is $(e_2^*)_{min} = \frac{\theta\lambda\eta_2}{d}$. When there is a certain degree of fairness preference among investors, the optimal decision levels of investors are $(a^*)_{max} = \frac{m-\delta_1}{b}\theta q \eta_1$ and $(e^*)_{min} = \frac{1+\delta_1 - m}{d}\lambda\eta_2$. A comparison of the optimal productive effort level before and after the investor is completely rational is $(\Delta a)_{max} = (a^*)_{max} - (a_2^*)_{max} = \frac{\delta_1 + \delta_2(\varepsilon - 1)\theta}{b}\theta q \eta_1$, and the difference in the optimal distributive effort levels is $(\Delta e)_{min} = (e^*)_{min} - (e_2^*)_{min} = \frac{\delta_2(1-\varepsilon)\theta - \delta_1}{d}\lambda\eta_2$. At this time, when investors have a certain degree of fairness preference in the horizontal and vertical dimensions, if and only if the parameters satisfy $\delta_1 + \delta_2(\varepsilon - 1)\theta = 0$, that is, when the value of the coefficient ε on the degree of fulfillment of the government's overpromise obtained by other investors satisfies $\varepsilon = 1 - \frac{\delta_1}{\delta_2 \cdot \theta}$, there is no difference in the productive effort level or distributive effort level of the investor before and after fairness preference; that is, $(a^*)_{max} = (a_2^*)_{max}$ and $(e^*)_{min} = (e_2^*)_{min}$, respectively. When the coefficient ε satisfies the condition that $\varepsilon > 1 - \frac{\delta_1}{\delta_2 \cdot \theta}$, the productive effort level of the investor under fair preference is greater; that is, $(a^*)_{max} > (a_2^*)_{max}$, and the level of speculative behavior is lower $(e^*)_{min} < (e_2^*)_{min}$. Conversely, when the coefficient ε satisfies $0 < \varepsilon < 1 - \frac{\delta_1}{\delta_2 \cdot \theta}$, investors are influenced by unfairness preference, the productive effort is lower and the distributive effort is greater in the PPP; that is, $(a^*)_{max} < (a_2^*)_{max}$ and $(e^*)_{min} > (e_2^*)_{min}$. Therefore, when investors exhibit a fairness preference and governments provide the highest-level intensity of incentives, the coefficient of the degree of fulfillment of governments' overcommitment obtained by other investors should satisfy $\varepsilon > 1 - \frac{\delta_1}{\delta_2 \cdot \theta}$; at this time, under fairness preferences, investors invest a greater level of productive effort, and the distributive effort level is thus effectively controlled.

5. Numerical example

Currently, the financial burden for infrastructure development often tends to exceed the level beyond which most governments cannot afford (Wang et al., 2020). It is critical for investors to evaluate the degree of government overcommitment fulfillment in advance. To describe the proposed model in this paper more intuitively and demonstrate its practicability and applicability, a numerical simulation is conducted in this section.

Elements such as project parameters and investors' personality characteristics can be obtained through questionnaires, personality tests, and Monte Carlo simulations. It is assumed that the guarantee level of the government is $R_e = 0.65$; the degree of investors' willingness to cooperate is $\tau = q\theta = 0.25$; the speculative tendency of investors is $\lambda = 0.1$; the economic benefits and speculative output coefficients of PPPs are $\eta_1 = 0.25$ and $\eta_2 = 0.1$, respectively; the corresponding output fluctuation is $\sigma_1^2 = \sigma_2^2 = 0.5$; and the social benefit coefficient of the project is $s = 0.15$. The unit effort costs of investors' productive and distributive efforts in a project are $b = 0.35$ and $d = 0.05$, respectively; investors' risk aversion coefficient is $\rho = 0.75$; and the fairness preference coefficients are $\delta_1 = 0.35$ and $\delta_2 = 0.25$, respectively. Additionally, according to an analysis of the local fiscal expenditure responsibility and an analysis of the project storage situation, investors estimate that the degree of government overcommitment fulfillment is $\theta = 0.5$. Assuming that the average degree of government overcommitment experienced by other investors is 85% of the degree of government overcommitment fulfillment experienced by the investors of this project, the coefficient $\varepsilon = 0.85$. Based on the different degrees of fairness preference of investors and of government overcommitment, the incentive mechanism of governments β^*, investors' optimal strategy choices a^* and e^*, and the respective returns of both parties U_{Inv} and U_g are shown in Table 6 below.

The optimal allocation ratio of governments β^* and optimal strategy choice for investors a^* and e^* are further analyzed. The continuous changing relationship between the degree of investors' fairness preference (δ_1 and δ_2) and the degree of government overcommitment fulfillment θ is shown in the Figure 1. When investors' vertical fairness preference stabilizes at a certain level (such as $\delta_1 = 0.85$) and the degree of government overcommitment fulfillment θ is held constant, the optimal proportion of output allocated by governments to investors β^* increases continuously with the increasing degree of horizontal fairness preference of investors δ_2. In contrast, if investors' fairness preference level remains unchanged, then the optimal distribution ratio of the project output β^* obtained by investors does not always increase with the decreasing degree of government overcommitment θ, showing an overall trend of first decreasing and then increasing.

The relationships among investors' optimal level of productive efforts a^*, their own horizontal fairness preference δ_2, and degree of government overcommitment θ are shown in Figure 2. Different from the trend of the project output distribution ratio obtained by investors, investors' optimal level of productive efforts a^* increases with an increasing degree of government overcommitment θ. In the government overcommitment scenario of a project,

Table 6. Incentive mechanisms under different investors' fairness preferences and government overcommitment

Serial number	Scenario	δ_1	δ_2	ε	θ	β^*	a^*	e^*	U_{Inv}	U_g	U
0	Basic model	0.35	0.25	0.85	0.5	0.827	0.112	0.075	0.335	–0.320	0.015
1	δ_1 changes	0	0.25	0.85	0.5	0.952	0.082	0.108	0.336	–0.322	0.014
		0.65				0.759	0.125	0.059	0.334	–0.319	0.015
		1				0.708	0.135	0.049	0.334	–0.319	0.015
2	δ_2 changes	0.35	0.1	0.85	0.5	0.822	0.113	0.074	0.327	–0.320	0.007
			0.55			0.838	0.111	0.076	0.349	–0.320	0.029
			0.99			0.854	0.109	0.078	0.371	–0.321	0.050
3	ε changes	0.35	0.25	0.1	0.5	0.874	0.107	0.080	0.396	–0.321	0.075
				1		0.818	0.113	0.074	0.322	–0.320	0.002
				1.5		0.791	0.116	0.070	0.282	–0.320	–0.038
4	$\delta_2 = 0$ and ε changes	0.35	0	0.85	0.5	0.818	0.113	0.074	0.322	–0.320	0.002
				0.5							
				1.1							
5	$\delta_2 = 1$ and ε changes	0.35	1	0.85	0.5	0.855	0.109	0.078	0.371	–0.321	0.050
				0.5		0.954	0.099	0.089	0.485	–0.321	0.164
				1.5		0.719	0.124	0.062	0.159	–0.319	–0.160
6	θ changes	0.35	0.25	0.85	0.65	0.976	0.151	0.07	0.434	–0.413	0.021
					0.55	0.867	0.124	0.074	0.368	–0.352	0.016
					0.35	0.762	0.084	0.066	0.235	–0.226	0.009
					0.15	0.828	0.050	0.014	0.101	–0.097	0.004

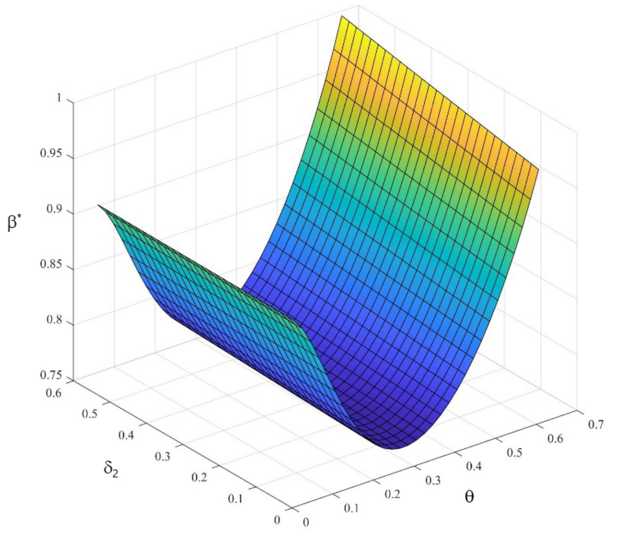

Figure 1. Relationship between investors' optimal allocation ratio β^* with θ and δ_2

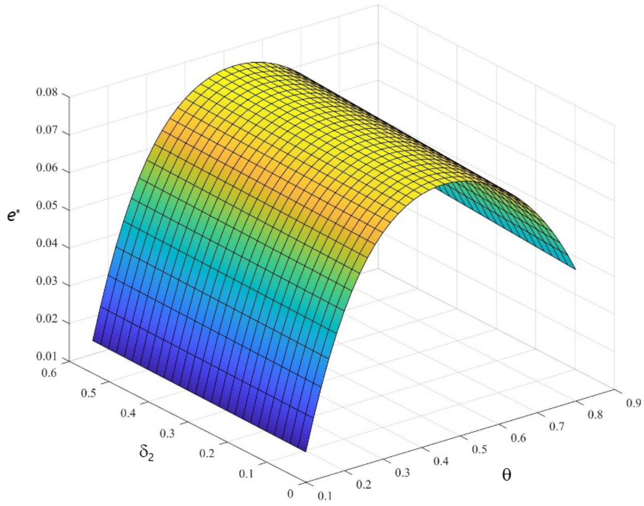

Figure 3. Relationship between investors' optimal distributive efforts level e^* with θ and δ_2

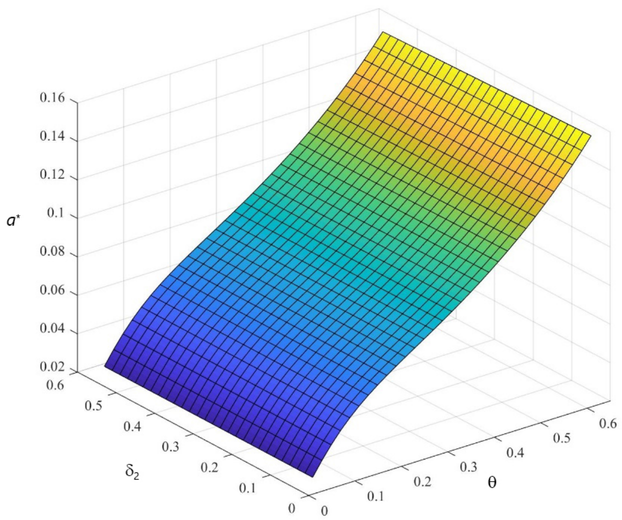

Figure 2. Relationship between investors' optimal level of productive efforts a^* with θ and δ_2

a greater degree of government overcommitment indicates a greater degree of incentive intensity; then, investors invest more in productive efforts. When the project parameters remain unchanged, the larger the horizontal fairness preference coefficient of investors δ_2 is, the lower the optimal level of productive efforts (i.e., a^* decreases with increasing δ_2).

Figure 3 reflects the relationships among the optimal distributive efforts e^* of investors in the government overcommitment scenario of PPPs, and their own horizontal fairness preference δ_2, and degree of government overcommitment θ. The results show that when the degree of government overcommitment fulfillment θ is unchanged, the larger the degree of investors' horizontal fairness preference δ_2 is, the more speculative the behavior exhibited by investors (i.e., e^* increases with increasing δ_2). However, in contrast, investors' optimal level of distributive efforts e^* and degree of government overcommitment θ show a trend of first increasing and then decreasing. According to Equation (22), the optimal distributive efforts of investors e^* form a monotonically decreasing function of the incentive intensity β^* of governments; therefore, the change trend of e^* with θ is opposite of that of β^* with θ, a finding that is consistent with the results of the numerical simulation. Through numerical simulation, the relationship between the optimal incentive intensity of governments β^* and the optimal strategies a^* and e^* for investors can be more clearly reflected, helping both parties improve their negotiation efficiency, thereby formulating and accelerating contract implementation.

6. Conclusions

As they can be fraught with various types of risk in PPPs, investors may not achieve their expected rate of return or even recover their investment during the operation stage. To this end, government guarantees have been an efficient measure through which to share these risks that may or may not materialize in the future. As a result, such government guarantees actually become a financial burden for local governments that often tend to exceed the level beyond which governments cannot afford. Once the guarantees that need to be fulfilled exceed the fiscal budget, governments are unable to fully fulfill them. In this scenario, government overcommitment occurs. However, the phenomenon and its impact on the incentives provided by governments have been overlooked in the previous literature. More importantly, little attention has been paid to the impact of investors' fairness preference on the optimal strategies for both parties. To bridge this gap, the objective of this paper is to formulate a mechanism of government overcommitment in PPPs based on investors' fairness preference.

The paper illustrates that the perception of investors' fairness preference includes two dimensions: fairness preference in the horizontal dimension, generated by a comparison with other investors participating in other PPPs, and fairness preference in a vertical dimension, generated by the principal-agent relationship between investors and governments. Consequently, a reasonable benefit distribution mechanism is particularly important in the scenario of government overcommitment. The results show that both the optimal strategies of governments and investors are usually affected by the degree of government overcommitment fulfillment, investors' fairness preference, and their willingness to cooperate. More specifically, the impacts of these factors on the optimal distribution of benefits and investors' optimal efforts are usually not monotonic. For instance, when the degree of investors' vertical fairness preference and the degree of government overcommitment fulfillment are held constant, the optimal proportion of output allocated to investors increases continuously with their strengthened horizontal fairness preference. In contrast, if the degree of investors' fairness preference remains unchanged, then the optimal distribution presents an overall trend of first decreasing and then increasing when the degree of government overcommitment fulfillment changes. With an increase in the degree of incentive intensity, the optimal productive efforts are improved and the optimal distributive efforts are weakened, accordingly and vice versa. When governments provide maximum-level incentive intensity, the productive efforts invested by investors reach their highest level and distributive efforts are minimized. Furthermore, even if governments provide the highest degree of incentive, the premise of investors participating in the project is $m - \delta_1 > 0$; that is, the coefficient ε needs to be $\varepsilon > \varepsilon_1$. Different from perceptual cognition, the premise of investors' productive efforts is that the average degree of government overcommitment to other investors satisfies $\varepsilon > \varepsilon_1$. In this scenario, when the degree of government overcommitment fulfillment is $\varepsilon \geq \varepsilon_2$, the opportunistic behavior of investors can be completely eliminated.

The contributions of this paper are to focus on the fulfillment degree of government guarantees in advance due to limited fiscal expenditure responsibilities in PPPs. Then, an incentive mechanism of such government overcommitment is proposed. Furthermore, the degree of investors' fairness preference is incorporated into this incentive, revealing the impacts of such fairness preference from both the horizontal and vertical dimensions. A fair distribution of benefits can be conducive to sustainable cooperation between the two parties and, ultimately, to the success of PPPs. The optimal strategies drawn in this article enable the structuring of a bargaining basis for both parties. Finally, the limitations of this work should be highlighted. Due to the confidentiality of PPPs, the data of real cases cannot be obtained for further quantitative analysis. Thus, the abovementioned numerical example demonstrates only one possible scenario. In the future, with the development of psychology and behavioral economics as well as technology, such behavioral preferences can be captured precisely. Additionally, some analysis concerning the distribution of government overcommitment fulfillment can be considered. Still, the findings contribute new insights into the incentive mechanism to innovatively work toward creating an effective contract to pay more attention to the risk of government overcommitment in advance in PPPs.

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