systems

MDPI

Article

Evolution Mechanism of Public–Private Partnership Project Trust from the Perspective of the Supply Chain

Huimin Li [1,*], Yu Zhang [1], Mengxuan Liang [1], Yongchao Cao [2], Wenjuan Zhang [1] and Limin Su [3]

[1] Department of Construction Engineering and Management, North China University of Water Resources and Electric Power, Zhengzhou 450046, China; x20211010199@stu.ncwu.edu.cn (Y.Z.); 201603616@stu.ncwu.edu.cn (M.L.); 201603212@stu.ncwu.edu.cn (W.Z.)
[2] School of Management and Economics, North China University of Water Resources and Electric Power, Zhengzhou 450046, China; 201610106059@stu.ncwu.edu.cn
[3] School of Mathematics and Statistics, North China University of Water Resources and Electric Power, Zhengzhou 450046, China; sulimin@ncwu.edu.cn
* Correspondence: lihuimin@ncwu.edu.cn; Tel.: +86-15039063656

Abstract: In the public–private partnership (PPP) supply chain, trust serves as the foundation for collaboration between investment companies and suppliers. However, due to many uncertain factors, the evolution of trust remains a "black box" phenomenon. In order to analyze the impact of the evolution of trust in the PPP supply chain on investment companies and suppliers' strategic choices, and promote the healthy and sustainable development of PPP supply chain projects, this paper establishes a trust evolutionary game model, which analyzes the evolutionary paths under different scenarios and explores the impact of parameters on the cooperative strategies of participants. The findings indicate that trust asymmetry or an increase in trust can facilitate investment companies and suppliers to opt for positive cooperation strategies. Furthermore, both parties' strategies are less influenced by their initial willingness and more by trust degree. The moral risk coefficient and information asymmetry coefficient have a negative effect on the cooperative strategies, with the moral risk coefficient of investment companies exhibiting a more significant impact on the entire cooperation process. Moreover, both parties can only choose positive strategies when the information asymmetry coefficient is low. This study holds significant implications for promoting cooperation, enhancing contract performance, safeguarding the interests of all parties, and increasing cooperation satisfaction.

Keywords: supply chain; PPP project; cooperation mechanism; stakeholder approach; trust; evolutionary game

Citation: Li, H.; Zhang, Y.; Liang, M.; Cao, Y.; Zhang, W.; Su, L. Evolution Mechanism of Public–Private Partnership Project Trust from the Perspective of the Supply Chain. *Systems* **2023**, *11*, 379. https://doi.org/10.3390/systems11070379

Academic Editor: Zhou He

Received: 15 June 2023
Revised: 20 July 2023
Accepted: 21 July 2023
Published: 23 July 2023

1. Introduction

PPP projects are long-term cooperation models that effectively alleviate the financial burden on the government and provide higher-quality public services to the public. They are widely used in various areas including transportation, municipal, medical, and elderly care. PPP projects are designed, built, operated, and serviced by the private sector, with collaboration between different participants. Meanwhile, construction supply chain management (CSCM) aims to achieve timely delivery of projects in the shortest possible time at the lowest economic or environmental cost [1]. By balancing various construction resources, cooperating with main participants, and integrating construction information, CSCM is conducive to optimizing projects and performance [2]. However, there are significant differences between the construction supply chain (CSC) and the PPP supply chain [3]. PPP project is the integration of CSC and broadens the chain of CSC. The PPP project supply chain is established on the basis of CSC, including finance, design, construction, and operation of the whole life cycle industry chain. On the other hand, CSC focuses on the construction process of engineering facilities, its core is the construction party, and pricing

is based on the bill of quantities of products. Due to the uncertain and random nature of the construction and implementation site of the product, the cooperation relationship between enterprises in the CSC is short-term and unstable.

In the supply chain of PPP projects, investment companies play a central role as the core participants, while suppliers provide infrastructure products and public services that align with the requirements of investors. Pricing in PPP projects is determined based on the quality of services provided, and the payment of service fees is contingent upon the project's performance. Additionally, the franchise period within the supply chain of PPP projects can extend up to 10–30 years, allowing the participants to establish a relatively stable long-term cooperative relationship in a specific location. This aspect proves advantageous for enhancing project performance optimization and facilitating the achievement of sustainable development objectives.

In a PPP supply chain, partners are frequently driven by unique objectives and value systems, resulting in conflicts of interest. As supply chain members build stronger cooperative relationships and capitalize on their individual strengths, enterprise collaboration becomes increasingly vital. The supply chain system is marked by its complexity and openness, necessitating harmonious cooperation among members for its establishment. To guarantee compatibility among participants, fostering amicable cooperation and mutual trust among supply chain enterprises is crucial, ultimately enhancing the quality of collaboration and elevating the competitiveness of the supply chain. Trust is a crucial factor for fostering friendly cooperation between supply chain enterprises [4]. It plays a vital role in any transactional relationship within the PPP supply chain, facilitating coordination and problem-solving efforts [5], promoting cooperative behavior among supply chain partners [6], and enhancing cooperation satisfaction [7]. However, to establish a stable cooperative relationship, upstream and downstream enterprises of the PPP supply chain must engage in numerous games and cooperation efforts. In the long-term evolutionary game process, it is essential to effectively improve the level of trust between investment companies and suppliers in the PPP supply chain, and to uncover the mechanism and mode of trust evolution between the parties involved. This is a critical issue that requires attention and resolution.

This paper aims to establish a PPP supply chain trust evolution game model, analyze the trust evolution trend of PPP supply chain participants under different circumstances, and investigate the influence of key factors on the strategy selection of both parties in the game. The main objectives of this study are to answer the following questions:

(1) What is the trust evolution law of each participant in the PPP supply chain?

(2) How do key factors affect the cooperation strategies of PPP supply chain participants?

The structure of this paper is as follows: Section 2 presents a literature review; Section 3 introduces the PPP supply chain trust evolution game model; Section 4 discusses the trust evolution law in each scenario through numerical simulation and analyzes the impact of key factors on the trust evolution of the PPP supply chain. Finally, Section 5 summarizes the findings of the study.

2. Literature Review

2.1. Trust in Construction Supply Chain

CSC is a sophisticated network comprising various project participants that is known for its ability to adapt and regulate itself, thus facilitating the synchronization of project progress, quality, and other objectives [8]. The core of CSC lies in the interconnection of relationships, which calls for the effective implementation of supply chain management (SCM) across the entire lifecycle of the project [9]. The concept of CSCM was initially introduced in 1992 [10], Hatmoko and Scott [11] defined CSCM as a system wherein contractors, suppliers, customers, and their representatives collaborate to ensure the provision and delivery of construction project resources, such as materials, equipment, temporary works, plants, labor, or other necessary resources. CSCM encompasses the coordination and allocation of information, logistics, and funds within the construction process, benefiting major con-

tractors and enabling them to navigate market fluctuations and enhance profitability [12]. All participants collaborate to augment the overall value of the supply chain [13,14], minimize supply chain costs [15], and actively influence project performance [16]. The supply chain system is characterized by openness and complexity, and its establishment relies on effective cooperation among its members. Shi et al. [17] pointed out that the evolution of the system toward a high trust equilibrium can be facilitated by increasing the anticipated benefits of trust, reducing the costs associated with trust, establishing a fair and effective mechanism for sharing benefits and risks, and emphasizing the significance of collaboration for both parties involved. Xia et al. [18] have emphasized the influential role of blockchain technology in the prefabricated building supply chain, specifically in terms of trust and performance. However, they note that blockchain technology primarily functions as an intermediary by fostering trust relationships. In an empirical study, Jagtap and Kamble [19] assessed the impact of project trust on project performance and found that project trust not only enhanced the dual factors within the CSC but also exerted an active influence on project performance. Similarly, Mora-Monge et al. [20] examined the impact of trust and power among trading partners on supply chain integration, with their findings underscoring the significance of trust and supply chain integration for business performance. Hence, trust assumes a critical role in promoting amicable cooperation among supply chain members.

2.2. Trust in PPP Projects

Trust plays a pivotal role in fostering amicable cooperation among participants in PPP projects [21,22]. Extensive evidence suggests that a strong supply chain relationship is often contingent on the level of trust between the involved parties. Mutual trust serves to mitigate cooperation risks, such as uncertainty and opportunism [21], while facilitating knowledge sharing [23] and fostering a greater willingness to collaborate [24].

Trust plays a vital role in fostering stable and loyal cooperative relationships [7,25–27]. It is a key factor in sustaining a successful supply chain partnership [28] and serves as the cornerstone for achieving partner relationship continuity, reflecting the long-term direction of the partnership. Trust is also recognized as one of the key factors that promote enduring cooperation among supply chain stakeholders [29].

Ren and Liu [30] conducted a study on the evolution process of stakeholder behavior in PPP projects. They identified the stable strategy for trust evolution and the key factors influencing trust behavior, with the aim of promoting the sustainable development of PPP projects. Du and Wang [31] identified and analyzed the factors that influence trust at each stage of a PPP project. They highlighted that the level of trust can be effectively adjusted by addressing these influencing factors. Guo et al. [32] investigated the bilateral moral hazard issues in PPP projects in China. They observed that a higher level of government moral hazard is associated with increased investment willingness in PPP projects, while also highlighting the coexistence of information asymmetry and moral hazard problems [33].

2.3. The Application of Evolutionary Game in Supply Chain

Evolutionary game theory, which combines game theoretic analysis with dynamic evolutionary processes, holds significant potential for modeling real-world problems [34]. In the context of evolutionary game theory, both players in the game are assumed to be rational yet bounded in their pursuit of evolutionarily stable strategies, aligning with the principles of biological evolution [35]. Unlike classical games, players in evolutionary games continuously adjust their strategies through learning and emphasize dynamic equilibrium [36]. The establishment of the PPP supply chain relies on the cooperative relationship between investment companies and suppliers, built upon trust. The supply chain can be viewed as an ecosystem, with each node representing a dynamic structure that possesses learning and computational capabilities [3]. Hence, evolutionary game theory finds extensive application in the exploration of supply chains and trust dynamics. Li et al. [3] investigated the stochastic evolution model of knowledge sharing within PPP

supply chains. They analyzed the impact of parameter variations on enterprise strategies and emphasized that enhancing the coefficient of mutual trust contributes to the formation of sharing strategies among partners. Hao et al. [37] employed evolutionary game theory to examine the evolutionary trajectory and stable strategies of knowledge-sharing behavior among enterprises in the CSC. Kang et al. [38] utilized evolutionary game theory to analyze enterprise behavior, government low-carbon strategies, and strategic concerns in the context of the emerging low-carbon market within low-carbon supply chains. They further established a two-level supply chain comprising retailers and suppliers. Sun et al. [39] constructed an evolutionary game model among accounts receivable insurance businesses by analyzing the factors influencing decision making in supply chain finance, specifically related to supply chain finance risk. In the realm of trust research, Li et al. [40] examined the organizational and coordination mechanisms of humanitarian supply chains. They developed an evolutionary game model incorporating both traditional mechanisms and trust mechanisms. Their findings revealed that trust has a significant positive influence on promoting coordination, particularly when supported by potential returns and high levels of trust.

Previous studies have acknowledged the importance of trust in promoting cooperation among participants in PPP projects. They have identified the lack of trust, information asymmetry, and moral hazard as significant factors contributing to the disharmony of cooperative relationships. However, there is a research gap when it comes to understanding the process of trust evolution among participants in PPP projects. Additionally, limited attention has been given to trust within PPP supply chain. This paper aims to fill these gaps by analyzing the mechanism and pattern of trust evolution between investment companies and suppliers in long-term cooperative relationships within the PPP supply chain. The findings of this study will contribute to fostering harmonious cooperative relationships between investment companies and suppliers, enhancing cooperation satisfaction, and ensuring seamless collaboration.

3. PPP Project Supply Chain Trust Evolution Game

3.1. Problem Description and Basic Assumptions

In the process of PPP project implementation, investment companies and suppliers need to carry out long-term and frequent cooperation and exchanges, so the cooperation between the various participants in the PPP supply chain needs to receive extensive attention. For example, the water environment management and ecological restoration project in Pingyu County, China is jointly funded by Henan Water Resources Investment Company and the local government, and the government and the investment company have 15% and 85% equity, respectively. Henan Water Resources Investment Company, the local government, and local construction units jointly established a Special-Purpose-Vehicle (SPV) project company to complete the design, construction, operation, and maintenance of the project. The SPV project company manages design suppliers, construction suppliers, operation, and maintenance suppliers, etc., to form a PPP supply chain. The investment company establishes long-term cooperative relations with multiple suppliers, and forms a stable supply chain through communication and collaboration, information sharing, and risk management. PPP project supply chain members, through continuous information interaction, coordination and sharing, establish an optimal and scalable network and eliminate redundant nodes in order to effectively manage the supply chain. Drawing upon a comprehensive examination of member trust levels, information asymmetry, and the degree of moral hazard within the supply chain, this paper delves into the cooperative relationships among members of the PPP supply chain by constructing an evolutionary game model. To facilitate a more effective investigation, the following fundamental hypotheses are proposed:

(1) Game player hypothesis. In the PPP supply chain model, the investment company serves as the core, while the suppliers are responsible for various aspects, such as the design, construction, equipment supply, and operation and maintenance of PPP projects.

The quality of the products and services provided is contingent upon the level of trust in their cooperation. Hence, this paper focuses on the game players, namely the investment companies and suppliers. Their relationship is illustrated in Figure 1.

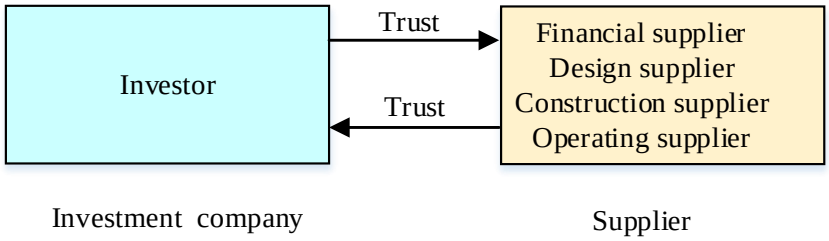

Figure 1. PPP supply chain trust evolutionary game players.

(2) Economic man hypothesis. It is assumed that PPP supply chain members consistently strive to maximize their benefits. They possess clear objective functions and opt for optimal strategy selection.

(3) Information asymmetry hypothesis. In the process of cooperation, the information held by both sides is asymmetrical. Information asymmetry may lead to the increase in supply and demand costs between supply chain partners, which has a negative impact on supply chain performance [41]. Assuming that the information asymmetry coefficient k_i is measurable ($0 < k_i < 1$), the change in the information asymmetry coefficient can affect the efficiency of the resources invested in the cooperation process [42], and its negative impact is $k_i S_i$. With the increase in information asymmetry coefficient, the efficiency of resources invested in the cooperation process will be greatly reduced.

(4) The moral hazard hypothesis. Moral hazard occurs in a cooperative relationship when one party maximizes its own utility and at the same time acts against others [43]. In the PPP supply chain, investment companies have two trust strategy choices: distrust and trust. Suppliers have two strategic options: active cooperation and negative cooperation. If one party adopts an active cooperation strategy and the other party negatively cooperates, it will bring a certain moral hazard benefit $l_i S_i$ to the negative party, but this situation is not conducive to the PPP supply chain to achieve the value maximization goal, and the opportunistic behavior should be punished [44].

(5) The hypothesis of trust between game agents. It is assumed that the trust among game players exists objectively, that the trust level α_i is measurable, and that the trust level changes with the deepening of the communication and cooperation of game players [45]. In the process of cooperation between investment companies and suppliers, the trust between investment companies and suppliers can promote the harmonious cooperation process. At this time, in addition to explicit benefits, such as material benefits M_i, the increased benefits also include implicit benefits $W_i (W_i = \alpha_i S)$, such as reputation, praise, etc. [46] $(W_i = \alpha_i S)$. It is assumed that the explicit benefit of active cooperation is greater than that of opportunistic behavior $M_i > l_i S_j - B_i$.

(6) Initially, the investment company has a probability $(1 - x)$ of choosing the distrust strategy, and a probability x of choosing the trust strategy. Similarly, the suppliers have a probability $(1 - y)$ of selecting negative cooperation and a probability y of opting for active cooperation.

Based on the aforementioned assumptions, an asymmetric evolutionary game model is developed to analyze trust dynamics between investment companies and suppliers, taking into account incomplete information and bounded rationality. Throughout the game process, both parties choose strategies that align with their respective interests. The strategy mix of the investment company and supplier, as well as the income payment matrix, are presented in Table 1,and the meanings of parameters are shown in Table 2.

Table 1. Income payment matrix.

Strategy		Supplier	
		Negative Cooperation	**Active Cooperation**
Investment company	Distrust	u_a,u_b	$u_a + l_a S_b - B_a$, $u_b - C_b - k_b S_b + A_b + W_b$
	Trust	$u_a - C_a - k_a S_a + A_a + W_a$, $u_b + l_b S_a - B_b$	$u_a - C_a - k_a S_a + A_a + M_a + W_a$, $u_b - C_b - k_b S_b + A_b + M_b + W_b$

Table 2. Model variables and their explanation.

Variable	Explanation
u_i	Benefits when investment companies and suppliers choose negative strategies
S_i	Resources invested when investment companies and suppliers choose negative strategies
k_i	Information asymmetry coefficient between investment companies and suppliers
α_i	Trust degree between investment companies and suppliers
l_i	Moral hazard coefficient between investment companies and suppliers
A_i	Government reward when investment companies and suppliers choose active strategies
B_i	Government punishment when investment companies and suppliers choose negative strategies
C_i	Costs when investment companies and suppliers choose active strategies
M_i	Explicit benefits when investment companies and suppliers choose active strategies
W_i	Hidden benefits when investment companies and suppliers choose active strategies

In Table 1, the active strategy refers to the trust behavior exhibited by the investment company and the active cooperation behavior demonstrated by the supplier. On the other hand, the negative strategy corresponds to the lack of trust displayed by the investment company and the negative cooperation behavior exhibited by the supplier. The i in Table 2 corresponds to the investment company and the supplier. The investment company is represented by a, and the supplier is represented by b.

In Table 1, when the investment company chooses distrust and the supplier chooses active cooperation, the incomes of the investment company are as follows: negative cooperation benefits + opportunistic behavior benefits; the incomes of suppliers are as follows: negative cooperation benefits + rewards of active cooperation + hidden benefits of active cooperation strategies—costs of active cooperation strategies—resources invested discounts caused by information asymmetry. When the investment company chooses trust behavior and the supplier chooses negative cooperation strategy, the incomes of the investment company are as follows: negative cooperation benefits + rewards of active cooperation + hidden benefits of active cooperation strategy—costs of active cooperation strategy—resources invested discounts caused by information asymmetry; the supplier's incomes are as follows: negative cooperation benefits + opportunistic behavior benefits. When both the investment company and the supplier cooperate actively, the incomes of both parties are as follows: negative cooperation benefits + rewards for active cooperation + hidden benefits of active cooperation strategies—costs of active cooperation strategies—resources invested discounts caused by information asymmetry + explicit benefits of both parties' active cooperation.

3.2. Game Model Construction

Based on the fundamental assumption of the evolutionary game and the income payment matrix presented for investment companies and suppliers, the following conclusions can be drawn:

The expected income of investment company when choosing the distrust behavior is

$$E_{a1} = (1 - y)u_a + y(u_a + l_a S_b - B_a) \tag{1}$$

The expected income of investment company when choosing the trust behavior is

$$E_{a2} = (1 - y)(u_a - C_a - k_a S_a + A_a + W_a) + y(u_a - C_a - k_a S_a + A_a + M_a + W_a) \tag{2}$$

The average income of investment companies is

$$\overline{E}_a = (1-x)E_{a1} + xE_{a2} \tag{3}$$

The expected income of the supplier when choosing the negative cooperation behavior is

$$E_{b1} = (1-x)u_b + x(u_b + l_b S_a - B_b) \tag{4}$$

The expected income of the supplier when choosing the active cooperation behavior is

$$E_{b2} = (1-x)(u_b - C_b - k_b S_b + A_b + W_b) + x(u_b - C_b - k_b S_b + A_b + M_b + W_b) \tag{5}$$

The average income of the supplier is

$$\overline{E}_b = (1-y)E_{b1} + yE_{b2} \tag{6}$$

The replication dynamic equation describes the evolution of group strategies over time [35]. Specifically, the replication dynamic equation for the investment company choosing the distrust behavior and the supplier opting for negative cooperation behavior is as follows:

$$f(x,y) = x(E_{a2} - \overline{E}_a) = x(1-x)[y(M_a + B_a - l_a S_b) + (A_a + W_a - C_a - k_a S_a)] \tag{7}$$

$$g(x,y) = y(E_{b2} - \overline{E}_b) = y(1-y)[x(M_b + B_b - l_b S_a) + (A_b + W_b - C_b - k_b S_b)] \tag{8}$$

3.3. Model Solving and Stability Analysis

The evolutionary stable strategy (ESS) point represents the state where the strategies of both sides in the game remain unchanged over time, indicating an equilibrium point in the game. To determine the equilibrium points of the evolutionary game and assess their stability, an analysis will be conducted.

Based on the replication dynamic Equations (7) and (8), which describe the dynamics of the investment company choosing the distrust behavior and the supplier opting for negative cooperation behavior, respectively, let $f(x,y) = 0$ and $g(x,y) = 0$, and solve for the five equilibrium points: $A(0,0)$, $B(0,1)$, $C(1,0)$, $D(1,1)$, $E(x_0, y_0)$. Among them, $0 < x_0 < 1, 0 < y_0 < 1$, $x_0 = \frac{-(A_b + W_b - C_b - k_b S_b)}{M_b + B_b - l_b S_a}$, $y_0 = \frac{-(A_a + W_a - C_a - k_a S_a)}{M_a + B_a - l_a S_b}$.

Based on the research findings of Friedman [34], the Jacobian matrix can be employed to assess whether the equilibrium point is an evolutionary stable strategy (ESS) point. The Jacobian matrix for Equations (7) and (8) is as follows:

$$J = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix}$$

where,

$$J_{11} = \frac{\partial f(x,y)}{\partial x} = (1-2x)[y(M_a + B_a - l_a S_b) + (A_a + W_a - C_a - k_a S_a)]$$

$$J_{12} = \frac{\partial f(x,y)}{\partial y} = x(1-x)(M_a + B_a - l_a S_b)$$

$$J_{21} = \frac{\partial g(x,y)}{\partial x} = y(1-y)(M_b + B_b - l_b S_a)$$

$$J_{22} = \frac{\partial g(x,y)}{\partial y} = (1-2y)[x(M_b + B_b - l_b S_a) + (A_b + W_b - C_b - k_b S_b)]$$

The determinant of the Jacobian matrix of the evolutionary game system composed of investment companies and suppliers can be expressed as $\det J = J_{11}J_{22} - J_{12}J_{21}$, and the trace of a matrix can be expressed as $tr\ J = J_{11} + J_{22}$. Let $\lambda_1 = A_a + W_a - C_a - k_a S_a$, $\lambda_2 = A_b + W_b - C_b - k_b S_b$, $\lambda_3 = (M_a + B_a - l_a S_b) + (A_a + W_a - C_a - k_a S_a)$, $\lambda_4 = (M_b + B_b - l_b S_a) + (A_b + W_b - C_b - k_b S_b)$; where λ_1 represents the scenario where supplier engages in negative cooperation, and in this case, the investment company obtains greater income from trust behavior compared to distrust behavior; λ_2 represents the scenario where the investment company chooses the distrust behavior, and in this case, the active cooperative behavior of the supplier generates more income compared to the negative cooperative behavior; λ_3 represents the scenario where the supplier engages in active cooperation, and in this case, the investment company obtains greater income from trust behavior compared to distrust behavior; and λ_4 represents the scenario where the investment company chooses trust behavior, and in this case, the active cooperative behavior of the supplier generates more income compared to the negative cooperative behavior. The $\det J$ and $tr\ J$ at each equilibrium point are shown in Table 3.

Table 3. $\det J$ and $tr\ J$ at equilibrium points.

Equilibrium Points	$\det J$	$tr\ J$
$A(0,0)$	$\lambda_1\lambda_2$	$\lambda_1 + \lambda_2$
$B(0,1)$	$-\lambda_2\lambda_3$	$\lambda_3 - \lambda_2$
$C(1,0)$	$-\lambda_1\lambda_4$	$\lambda_4 - \lambda_1$
$D(1,1)$	$\lambda_3\lambda_4$	$-\lambda_3 - \lambda_4$
$E(x_0, y_0)$	$-(1-x_0)(1-y_0)\lambda_1\lambda_2$	0

The stability of the equilibrium point can be judged in the following ways [35]: when the equilibrium point satisfies $\det > J$ and $tr\ J < 0$, the equilibrium point is an ESS point. When the equilibrium point satisfies $\det > J$ and $tr\ J > 0$, the equilibrium point is not an ESS point. When the equilibrium satisfies $\det < J$, the equilibrium is a saddle point. The model assumes that $\lambda_3 > \lambda_1$ and $\lambda_4 > \lambda_2$. The stability judgment results of each equilibrium point are shown in Table 4.

Table 4. Stability judgment of equilibrium point.

Scenario	Condition	Equilibrium Point Stability				
		$A(0,0)$	$B(0,1)$	$C(1,0)$	$D(1,1)$	$E(x_0,y_0)$
Scenario1	$\lambda_3 > \lambda_1 > 0,\ \lambda_4 > \lambda_2 > 0$	unstable	saddle	saddle	ESS	saddle
Scenario 2	$\lambda_3 > \lambda_1 > 0,\ 0 > \lambda_4 > \lambda_2$	saddle	unstable	ESS	saddle	uncertain
Scenario 3	$\lambda_3 > \lambda_1 > 0,\ \lambda_4 > 0 > \lambda_2$	saddle	unstable	saddle	ESS	uncertain
Scenario 4	$\lambda_3 > 0 > \lambda_1,\ \lambda_4 > \lambda_2 > 0$	saddle	unstable	unstable	ESS	uncertain
Scenario 5	$\lambda_3 > 0 > \lambda_1,\ 0 > \lambda_4 > \lambda_2$	ESS	unstable	saddle	saddle	saddle
Scenario 6	$\lambda_3 > 0 > \lambda_1,\ \lambda_4 > 0 > \lambda_2$	ESS	unstable	unstable	ESS	saddle
Scenario 7	$0 > \lambda_3 > \lambda_1,\ \lambda_4 > \lambda_2 > 0$	saddle	ESS	unstable	saddle	uncertain
Scenario 8	$0 > \lambda_3 > \lambda_1, 0 > \lambda_4 > \lambda_2$	ESS	saddle	saddle	unstable	saddle
Scenario 9	$0 > \lambda_3 > \lambda_1,\ \lambda_4 > 0 > \lambda_2$	ESS	saddle	unstable	saddle	saddle

As can be seen from Table 4, under conditions 1, 3, 4, and 6, (1,1) is an ESS point; under conditions 2, (1,0) is an ESS point; under conditions 5, 6, 8, and 9, (0,0) is an ESS point; and under conditions 7, (0,1) is an ESS point. Although ESS points may be the same in different conditions, they take different paths to reach ESS points. Section 3.4 will analyze the evolution path of equilibrium points in each condition in detail.

3.4. Evolutionary Path Analysis

Under scenario 1, Figure 2a illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stable strategy is (1,1), indicating that both parties consistently choose trust behavior and active cooperation. Initially, due to

constraints in input resources and costs, both investment companies and suppliers opt for a negative strategy. However, this strategy hinders friendly cooperation and value increment in PPP supply chain projects. To alter this state, the government intervenes by increasing the rewards for active cooperation and implementing stricter punishments for opportunistic behavior through institutional mechanisms. As the reward and explicit income associated with active cooperation surpass the input resources and costs, investment companies evolve toward trust behavior, and suppliers shift toward active cooperation. Additionally, under the constraints of penalties for opportunistic behavior, when one party chooses an active strategy, the other party is compelled to follow suit. As a result, the game system gradually evolves toward the strategy of active cooperation for both parties, reaching a stable state.

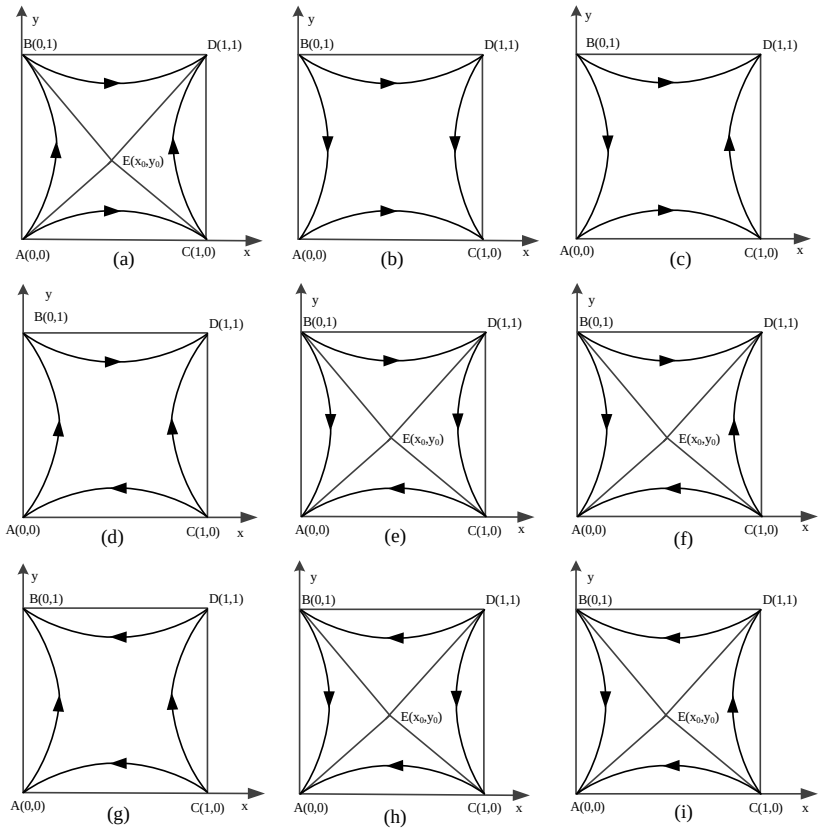

Figure 2. Phase diagram of evolutionary game under different scenarios. (**a**–**i** corresponds to the evolution paths of each equilibrium point in Scenarios 1–9 in Table 4).

Under scenario 2, Figure 2b illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stable strategy is (1,0), indicating that the investment company consistently chooses trust behavior while the supplier persists with negative cooperation behavior. Initially, when suppliers cooperate actively, the investment company's distrust strategy yields higher income. Consequently, the investment company exhibits opportunistic behavior. To regulate the market order, the government intervenes by imposing stricter punishments for opportunistic behaviors and offering greater rewards for trust behaviors. As a result, the income obtained from trust behaviors by the investment company surpasses the input resources and costs associated with trust behaviors, leading to the evolution of investment companies toward trust behavior. However, for suppliers, regardless of whether the investment company is trusted or not, their negative cooperation behavior generates greater benefits. The government's punishment for suppliers' opportunistic behavior and reward for active cooperation behavior are insufficient to offset the input resources and costs associated with suppliers' active cooperation behavior. Consequently, suppliers ultimately evolve toward negative cooperation behavior.

Under scenario 3, Figure 2c illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stable strategy is (1,1), indicating that both the investment company and the supplier consistently choose trust behavior and active cooperation, respectively. In the initial state, if the investment company opts for trust behavior, the government must provide a reward for the supplier's active cooperation that surpasses the input resources and costs associated with active cooperation. Failure to meet this condition would result in the supplier evolving toward the negative cooperation strategy. For investment companies, if the punishment for opportunistic behavior outweighs the moral hazard income, investment companies will evolve toward a trust strategy. Once the investment company selects the trust strategy, suppliers are compelled to choose the active cooperation strategy. As a result, the game system ultimately evolves toward the trust strategy of the investment company and the active cooperation strategy of the suppliers, achieving stability.

Under scenario 4, Figure 2d illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stable strategy is (1,1), indicating that both the investment company and the supplier consistently choose trust behavior and active cooperation, respectively. In the initial state, if the investment company selects the trust strategy, the government will impose penalties on the supplier for engaging in opportunistic behavior. When the magnitude of punishment exceeds the moral hazard income, the supplier will transition from negative cooperative behavior to active cooperative behavior. For investment companies, the input resources and costs associated with trust behavior outweigh the rewards and explicit income derived from trust behavior. As a result, investment companies evolve toward distrust behavior. However, when the government increases the punishment for distrust behavior and encourages suppliers to engage in active cooperation, investment companies shift toward trust behavior. The ultimate equilibrium in the game system is characterized by investment companies adopting the trust strategy, suppliers adopting the active cooperation strategy, and achieving stability.

Under scenario 5, Figure 2e illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stable strategy is (0,0), indicating that both the investment company and the supplier consistently choose distrust behavior and negative cooperation, respectively. In the initial state, the investment company opts for the distrust strategy while the supplier chooses the active cooperation strategy. With the influence of government rewards and punishments, investment companies evolve toward trust behavior. If the income derived from trust behavior is lower than the input resources and costs associated with trust behavior, investment companies will persist with the trust behavior. For suppliers, when the rewards and benefits of active cooperation fall short of the input resources and costs associated with active cooperation, suppliers will opt for the negative cooperation strategy. The final equilibrium in the game system is characterized by the investment company maintaining the trust strategy, suppliers adopting the negative cooperation strategy, and achieving stability.

Under scenario 6, Figure 2f illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stable strategies are (0,0) and (1,1). (0,0) indicates that the investment company chooses distrust behavior and the supplier chooses negative cooperation strategy; (1,1) indicates that the investment company chooses trust behavior and the supplier chooses active cooperation strategy. In the initial state, the investment company and the supplier may choose the positive cooperation strategy or the negative cooperation strategy. With the government's increased rewards and punishments, both investment companies and suppliers evolve toward the strategy of active cooperation. However, if the rewards and benefits associated with the active cooperative strategy are lower than the input resources and costs, both players will transition to the negative strategy. The final equilibrium in the game system can take one of two forms: either the investment company adopts a distrust strategy while the suppliers choose negative cooperation, or the investment company embraces trust behavior while the suppliers opt for active cooperation. In both cases, the game system achieves stability.

Under Scenario 7, Figure 2g illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stability strategy is (0,1), whereby the investment company chooses to distrust while the supplier opts for active cooperation. In the initial state, the investment company selects the trust strategy while the supplier chooses the negative cooperation strategy. For suppliers, if the government's rewards and explicit benefits outweigh the loss benefits of active cooperation, they will evolve toward the active cooperation strategy. On the other hand, if the income and reward of the trust strategy are lower than the input resources and costs of the trust strategy for investment companies, they will evolve toward the distrust strategy. Even with the supplier choosing the active cooperation strategy, they still maintain the distrust strategy. Ultimately, the game system evolves toward a strategy of distrust for investment companies and active cooperation for suppliers, leading to stability.

Under Scenario 8, Figure 2h illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stability strategy is represented by (0,0). Initially, the investment company is trusted and suppliers are actively cooperative. However, the rewards and income of the investment company's trust behavior are lower than the input resources and costs involved. Similarly, the rewards and benefits of the supplier's active cooperation behavior are lower than the input resources and costs, leading to the supplier adopting a negative strategy. Subsequently, the government imposes stricter punishments on opportunistic behavior and disregards the rewards of active cooperation strategy. Eventually, the game system evolves toward a state of investment company distrust and negative cooperation from suppliers, which reaches a stable state.

Under Scenario 9, Figure 2i illustrates the path of the trust evolution game between investment companies and suppliers. The evolutionary stability strategy is (0,0). Initially, the investment company opts for the trust strategy, while the supplier chooses negative cooperation. Investment companies may switch to the distrust strategy when the rewards and implicit income from trust behavior fail to offset the input resources and costs, or when the income from opportunistic behavior exceeds that of trust behavior. Conversely, suppliers may evolve toward active cooperation when the rewards and implicit benefits of such behavior outweigh the resources input and associated costs. However, if the investment company opts for distrust and the government's reward or punishment for the supplier is minimal, the supplier may switch to negative cooperation. Ultimately, the game system evolves toward the strategy of investment company distrust and supplier negative cooperation, reaching a stable state.

4. Numerical Simulation and Discussion

4.1. Evolutionary Path Simulation

According to the evolutionary path analysis presented in Section 3.4, there exist nine distinct evolutionary scenarios for the cooperation strategy between investment companies and suppliers, each characterized by different constraints. To provide a more visual representation of the evolutionary process across these scenarios, numerical simulations are conducted to analyze the strategy's evolution under various initial states and time ranges. The X-axis denotes the proportion of the investment company's trust strategy, while the Y-axis represents the proportion of the supplier's active cooperation strategy. Assume that the time range $t = [0, 100]$. In the initial state, $t = [0, 100]$ are, respectively, $[0.1, 0.9]$, $[0.2, 0.8]$, $[0.3, 0.7]$, $[0.4, 0.6]$, $[0.5, 0.5]$, $[0.6, 0.4]$, $[0.7, 0.3]$, $[0.8, 0.2]$, $[0.9, 0.1]$; $S_a = 5$, $K_a = 0.3$, $W_a = 2.2$, $S_b = 6$, $K_b = 0.2$, $W_b = 2.9$. The effects of each parameter on the system result is shown in Table 5.

Scenario 1: In the case when the $A_a = 6$, $C_a = 3$, $M_a = 1.8$, $B_a = 5$, $l_a = 0.8$, $A_b = 6$, $C_b = 4$, $M_b = 1.8$, $B_a = 5$, and $l_a = 0.8$ satisfy $\lambda_3 > \lambda_1 > 0$, $\lambda_4 > \lambda_2 > 0$, the simulation results are illustrated in Figure 3a. Under these circumstances, when the costs associated with the active cooperation strategy are relatively low and the government's rewards or punishments are significant, the cooperation strategy between the investment company and

the supplier evolves toward a mutually beneficial approach. This entails the investment company maintaining trust while actively engaging in cooperation with the supplier.

Table 5. The effects of each parameter on the system result.

Scenario	Condition	Parameter Setting															ESS
		S_a	k_a	W_a	A_a	C_a	M_a	B_a	l_a	S_b	k_b	W_b	A_b	C_b	M_b	B_b	l_b	
Scenario1	$\lambda_3 > \lambda_1 > 0,\ \lambda_4 > \lambda_2 > 0$	5	0.3	2.2	6	3	1.8	5	0.8	6	0.2	2.9	6	4	1.8	5	0.8	$D(1,1)$
Scenario 2	$\lambda_3 > \lambda_1 > 0,\ 0 > \lambda_4 > \lambda_2$	5	0.3	2.2	3	3	1.8	3.2	0.8	6	0.2	2.9	3	6	1.8	3.2	0.8	$C(1,0)$
Scenario 3	$\lambda_3 > \lambda_1 > 0,\ \lambda_4 > 0 > \lambda_2$	5	0.3	2.2	4	4	1.8	5	0.8	6	0.2	2.9	4	6	1.8	5	0.7	$D(1,1)$
Scenario 4	$\lambda_3 > 0 > \lambda_1, \lambda_4 > \lambda_2 > 0$	5	0.3	2.2	5	6	1.8	5	0.8	6	0.2	2.9	5	4	1.8	5	0.8	$D(1,1)$
Scenario 5	$\lambda_3 > 0 > \lambda_1,\ 0 > \lambda_4 > \lambda_2$	5	0.3	2.2	3	5	1.8	5	0.8	6	0.2	2.9	3	6	1.8	3	0.8	$A(0,0)$
Scenario 6	$\lambda_3 > 0 > \lambda_1,\ \lambda_4 > 0 > \lambda_2$	5	0.3	2.2	3	5	1.8	5	0.8	6	0.2	2.9	3	6	1.8	5	0.7	$A(0,0)\ D(1,1)$
Scenario 7	$0 > \lambda_3 > \lambda_1,\ \lambda_4 > \lambda_2 > 0$	5	0.3	2.2	3	5	1.8	3	0.8	6	0.2	2.9	6	4	1.8	5	0.8	$B(0,1)$
Scenario 8	$0 > \lambda_3 > \lambda_1, 0 > \lambda_4 > \lambda_2$	5	0.3	2.2	3	6	1.8	3	0.8	6	0.2	2.9	3	6	1.8	3	0.8	$A(0,0)$
Scenario 9	$0 > \lambda_3 > \lambda_1,\ \lambda_4 > 0 > \lambda_2$	5	0.3	2.2	3	6	1.8	3	0.8	6	0.2	2.9	3	6	1.8	5	0.8	$A(0,0)$

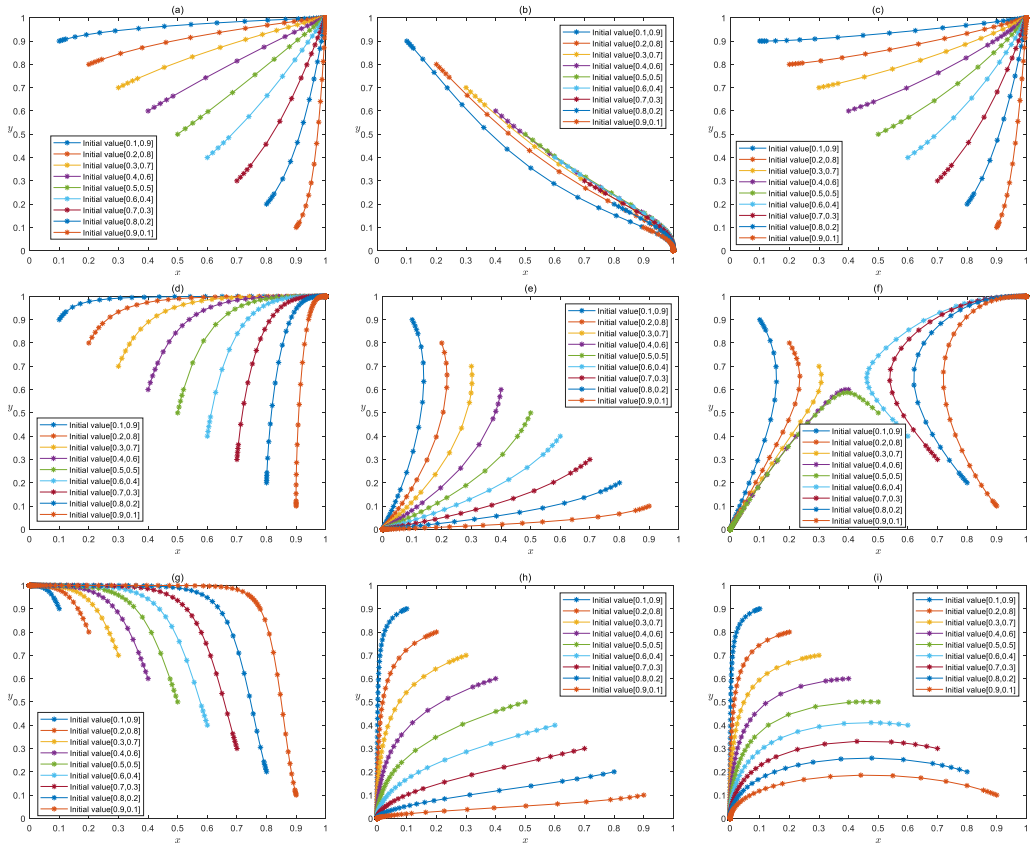

Figure 3. Simulation results of scenario 1–9. (**a–i** corresponds to the simulation result in Scenarios 1–9 in Table 4).

Scenario 2: In the case when the $A_a = 3$, $C_a = 3$, $M_a = 1.8$, $B_a = 3.2$, $l_a = 0.8$, $A_b = 3$, $C_b = 6$, $M_b = 1.8$, $B_a = 3.2$, and $l_a = 0.8$ satisfy $\lambda_3 > \lambda_1 > 0$, $0 > \lambda_4 > \lambda_2$, the simulation results are illustrated in Figure 3b. Under these circumstances, when the intensity of government rewards and punishments is low, the trust behavior of the investment company leads to higher income, whereas the opportunistic behavior of the supplier also yields higher income. Consequently, investment companies opt for a trust strategy, while suppliers adopt a negative cooperation strategy.

Scenario 3: In the case where $A_a = 4$, $C_a = 4$, $M_a = 1.8$, $B_a = 5$, $l_a = 0.8$, $A_b = 4$, $C_b = 6$, $M_b = 1.8$, $B_b = 5$, and $l_b = 0.7$ satisfy $\lambda_3 > \lambda_1 > 0$, $\lambda_4 > 0 > \lambda_2$, the simulation results are presented in Figure 3c. Under these circumstances, both parties experience low income from opportunistic behaviors, and the cost associated with the investment

company's trust behavior is also low. Considering the influence of government reward measures and hidden benefits, the investment company decides to adopt a trust strategy. Despite the relatively high cost of active cooperation for suppliers, the rewards and hidden benefits derived from active cooperation outweigh the cost, leading suppliers to choose an active cooperation strategy.

Scenario 4: In the case where $A_a = 5$, $C_a = 6$, $M_a = 1.8$, $B_a = 5$, $l_a = 0.8$, $A_b = 5$, $C_b = 4$, $M_b = 1.8$, $B_b = 5$, and $l_b = 0.8$ satisfy $\lambda_3 > 0 > \lambda_1, \lambda_4 > \lambda_2 > 0$, the simulation results are displayed in Figure 3d. Under these circumstances, both parties observe lower returns from their opportunistic behaviors, while the cost associated with suppliers' active cooperation behavior remains low. Considering the influence of government reward measures and hidden benefits, suppliers opt for the active cooperation strategy. Despite the investment company incurring a high cost for trust behavior, the rewards and hidden benefits derived from trust behavior are substantial enough to offset this cost, leading the investment company to choose the trust strategy.

Scenario 5: In the case where $A_a = 3$, $C_a = 5$, $M_a = 1.8$, $B_a = 5$, $l_a = 0.8$, $A_b = 3$, $C_b = 6$, $M_b = 1.8$, $B_b = 3$, and $l_b = 0.8$ satisfy $\lambda_3 > 0 > \lambda_1$, $0 > \lambda_4 > \lambda_2$, the simulation results are depicted in Figure 3e. Under these circumstances, when the cost associated with the active cooperation strategy between suppliers and investment companies is high, and the government fails to provide rewards for the active cooperation strategy, both parties evolve toward a negative cooperation strategy.

Scenario 6: In the case where $A_a = 3$, $C_a = 5$, $M_a = 1.8$, $B_a = 5$, $l_a = 0.8$, $A_b = 3$, $C_b = 6$, $M_b = 1.8$, $B_b = 5$, and $l_b = 0.7$ satisfy $\lambda_3 > \lambda_1 > 0$, $\lambda_4 > 0 > \lambda_2$, the simulation results are presented in Figure 3f. In this scenario, the government applies more severe punishments for opportunistic behavior while offering limited rewards for the active cooperation strategy. Under these circumstances, when one party chooses the active cooperation strategy, the other party will subsequently choose the corresponding strategy in response.

Scenario 7: In the case where $A_a = 3$, $C_a = 5$, $M_a = 1.8$, $B_a = 3$, $l_a = 0.8$, $A_b = 6$, $C_b = 4$, $M_b = 1.8$, $B_b = 5$, and $l_b = 0.8$ satisfy $0 > \lambda_3 > \lambda_1, \lambda_4 > \lambda_2 > 0$, the simulation results are illustrated in Figure 3g. Under these circumstances, investment companies face high costs associated with trust behavior, and the level of government rewards is relatively low. Consequently, investment companies opt for a strategy of distrust. On the other hand, suppliers observe increased income from the active cooperation strategy, which sufficiently compensates for the associated costs. Moreover, the penalties imposed on the negative cooperation strategy are substantial, leading suppliers to choose the active cooperation strategy.

Scenario 8: In the case where $A_a = 3$, $C_a = 6$, $M_a = 1.8$, $B_a = 3$, $l_a = 0.8$, $A_b = 3$, $C_b = 6$, $M_b = 1.8$, $B_b = 3$, and $l_b = 0.8$ satisfy $0 > \lambda_3 > \lambda_1$, $0 > \lambda_4 > \lambda_2$, the simulation results are presented in Figure 3h. Under these circumstances, the cost associated with the active cooperation strategy between investment companies and suppliers is high. Additionally, the government adopts a relaxed regulatory stance. Under these conditions, both investment companies and suppliers opt for a negative cooperation strategy.

Scenario 9: In the case where $A_a = 3$, $C_a = 6$, $M_a = 1.8$, $B_a = 3$, $l_a = 0.8$, $A_b = 3$, $C_b = 6$, $M_b = 1.8$, $B_b = 5$, and $l_b = 0.8$ satisfy $0 > \lambda_3 > \lambda_1$, $\lambda_4 > 0 > \lambda_2$, the simulation results are depicted in Figure 3i. When compared with scenario 8, the cost of active cooperation between investment companies and suppliers is still very high. Although the government has increased the punishment on negative cooperation behaviors of suppliers, the incomes of negative cooperation between investment companies and suppliers is higher. Therefore, investment companies and suppliers maintain negative cooperation strategies.

4.2. Parameter Analysis

The cooperation strategy adopted by each participant in the PPP supply chain is influenced by multiple factors. In this section, Scenario 6 is selected as an example to examine the impact of key dynamic influencing factors, including the trust degree, moral

hazard coefficient, and information asymmetry coefficient, on the cooperation strategy of investment companies and suppliers.

4.2.1. The Influence of Trust Degree on the Evolutionary Strategy of Two Game Players

In PPP projects, the impact of trust degree between an investment company and supplier on their evolutionary strategies can be analyzed from the following perspectives: (I) the asymmetry of trust between an investment company and supplier; (II) the scenario where the trust degree of one party remains constant while the trust degree of the other party changes in the cooperation between the investment company and supplier; (III) the consistency in trust degree between the investment company and supplier. These possible scenarios are simulated to analyze the influence of changes in trust degree between the investment company and supplier on the cooperation strategy of both parties. The results are presented in Figures 4–7, where the x-axis represents the evolution time, and the y-axis represents the cooperation willingness of the investment company and supplier.

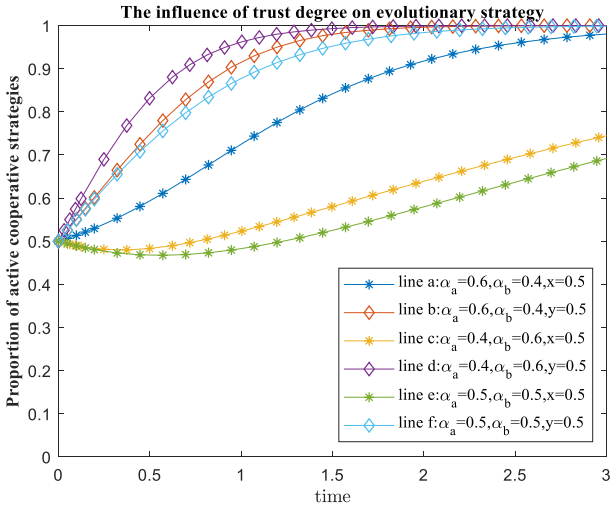

Figure 4. Evolution results of investment companies and suppliers when trust is asymmetric.

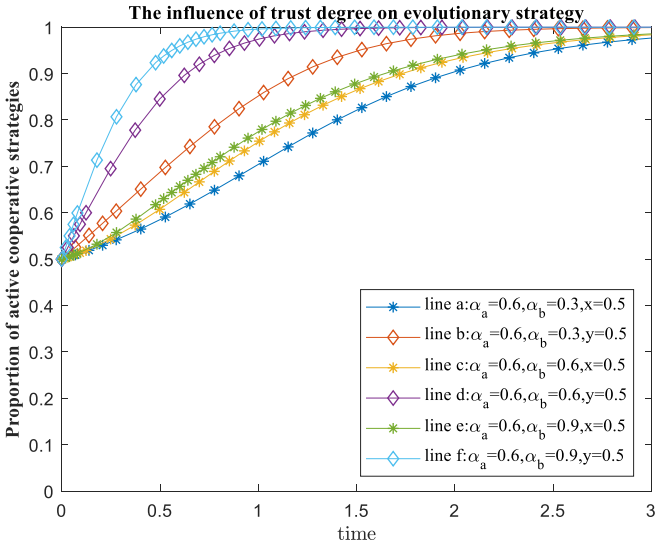

Figure 5. The influence of the unchanged degree of trust of the investment company to the supplier and the change of the trust degree of the supplier to the investment company on the cooperation strategy of both parties.

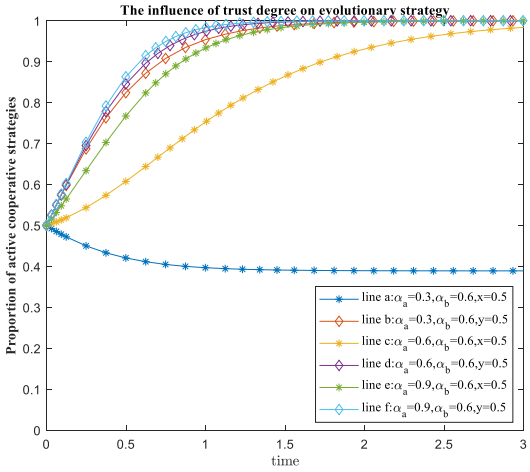

Figure 6. The influence of the unchanged degree of trust of the supplier to the investment company and the change of the trust degree of the investment company to the supplier on the cooperation strategy of both parties.

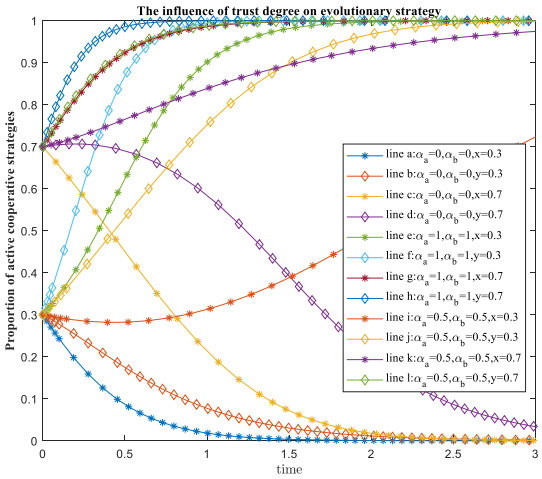

Figure 7. When the trust degree between the investment company and the supplier is consistent, the cooperation strategy of both sides is affected by the initial willingness.

(I) The influence of asymmetry of trust between an investment company and supplier on cooperation strategies. Suppose that the trust degree of the investment company to the supplier and the trust degree of the supplier to the investment company (α_a,α_b) are (0.6,0.4), (0.4,0.6), and (0.5,0.5), where (0.6,0.4) and (0.4,0.6) represent the asymmetry of trust between the investment company and the supplier. (0.5,0.5) represents the trust symmetry between the investment company and the supplier. Suppose that the initial cooperation willingness of the investment company is $x = 0.5$, the initial cooperation willingness of the supplier is $y = 0.5$, and the evolution result of the cooperation strategy of both parties is shown in Figure 4.

According to the evolution results of Figure 4, we can see that (i) if the investment company trusts the supplier more ($\alpha_a > \alpha_b$), the evolution results of the asymmetric trust between the investment company and the supplier are line a and line b, and both the investment company and the supplier choose the active cooperation strategy. For investment companies, by comparing the evolution results of consistent trust ($\alpha_a = 0.5$, $\alpha_b = 0.5$, line e) and asymmetric trust ($\alpha_a = 0.6$, $\alpha_b = 0.4$, line a) between investment companies and suppliers, it can be found that the asymmetry of trust leads to the acceleration of the evolution of investment companies toward the active cooperation strategy. For suppliers, comparing the evolution results of consistent trust ($\alpha_a = 0.5$, $\alpha_b = 0.5$, line f) and asymmetric trust ($\alpha_a = 0.6$, $\alpha_b = 0.4$, line b) between investment companies and suppliers, it can be found

that the asymmetry of trust leads to the acceleration of suppliers' evolution toward the active cooperation strategy. (ii) If the supplier trusts the investment company more ($\alpha_a < \alpha_b$), the evolution results of the asymmetric trust between the investment company and the supplier are line c and line d. and both the investment company and the supplier choose the active cooperation strategy. For investment companies, by comparing the evolution results of consistent trust ($\alpha_a = 0.5$, $\alpha_b = 0.5$, line e) and asymmetric trust ($\alpha_a = 0.4$, $\alpha_b = 0.6$, line c) between investment companies and suppliers, it can be found that the asymmetry of trust leads to the acceleration of the evolution of investment companies toward the active cooperation strategy. For suppliers, by comparing the evolution results of consistent trust ($\alpha_a = 0.5$, $\alpha_b = 0.5$, line f) and asymmetric trust ($\alpha_a = 0.4$, $\alpha_b = 0.6$, line d) between investment companies and suppliers, it can be found that the asymmetry of trust leads to the acceleration of the evolution of suppliers toward the active cooperation strategy. By comparing the evolution results of asymmetric trust between investment companies and suppliers (line a, line b, line c, line d) with those of consistent trust level (line a, line b), it can be found that a certain degree of asymmetry of trust accelerates the evolution of investment companies and suppliers toward active cooperation strategy. Moreover, it plays an active incentive role in the cooperation strategies of investment companies and suppliers in PPP projects.

(II) When the degree of trust between the investment company and the supplier has one side that does not change while the other side changes, the influence of the evolving strategy of the cooperation between the investment company and the supplier is analyzed. The following two conditions are assumed: (i) the trust degree of the investment company to the supplier remains unchanged ($\alpha_a = 0.6$), while the trust degree of the supplier to the investment company changes ($\alpha_b = 0.3, 0.6, 0.9$); and (ii) the degree of trust of the supplier to the investment company remains unchanged ($\alpha_b = 0.6$), and the degree of trust of the investment company to the supplier changes ($\alpha_a = 0.3, 0.6, 0.9$). Suppose that the initial cooperation willingness of the investment company is $x = 0.5$, and the initial cooperation willingness of the supplier is $y = 0.5$. The evolution results of the cooperation strategy of both parties are shown in Figures 5 and 6.

(i) According to the simulation results in Figure 5, as a whole, if the trust degree of the investment company to the supplier remains unchanged ($\alpha_a = 0.6$), the trust degree of the supplier to the investment company α_b increases from 0.3 to 0.9 (line b, line d, line f). The investment company and the supplier will accelerate the evolution of the active cooperation strategy (line a, line b, line c, line d, line e, line f). At this time, the increasing trust of the supplier to the investment company has an active incentive effect on the cooperation strategy of both parties. Further analysis shows that for suppliers, when the trust degree of the investment company to the supplier remains unchanged ($\alpha_a = 0.6$), and the trust degree of the supplier to the investment company α_b increases from 0.3 to 0.9, the evolution speed of the supplier to the active cooperation strategy accelerates obviously (line b, line d, line f). For the investment company, when the trust degree of the investment company to the supplier remains unchanged ($\alpha_a = 0.6$), and the trust degree of the supplier to the investment company α_b increases from 0.3 to 0.9 (line b, line d, line f), there is no obvious change in the evolution speed of investment companies to the active cooperation strategy (line a, line c, line e). Therefore, when the trust degree of the investment company to the supplier remains unchanged ($\alpha_a = 0.6$) and the trust degree of the supplier to the investment company α_b increases from 0.3 to 0.9 (line b, line d, line f), it can accelerate the evolution of the investment company and the supplier toward the active cooperation strategy. Moreover, the active incentive effect on the cooperation strategy of suppliers is more significant.

(ii) According to the simulation results in Figure 6, as a whole, if the trust degree of the supplier to the investment company remains unchanged ($\alpha_b = 0.6$), the trust degree of the investment company to the supplier, α_a, increases from 0.3 to 0.9 (line a, line c, line e). The evolution speed of suppliers toward the active cooperation strategy will be accelerated (line b, line d, line f), and the cooperation strategy of investment companies

will be transformed from negative cooperation to active cooperation (line a, line c, line e). At this time, the increasing trust of the investment company to the supplier has an active incentive effect on the cooperation strategy of both parties. Further analysis shows that for investment companies, when the trust degree of suppliers to investment companies remains unchanged ($\alpha_b = 0.6$), and the trust degree of investment companies to suppliers α_a increases from 0.3 to 0.6 (line a, line c), the cooperation strategy of investment companies is transformed from negative cooperation to active cooperation. Therefore, there exists a degree of trust of investment companies to suppliers between 0.3 and 0.6, which is the critical point for investment companies to transform their cooperation strategies from negative to active. When the trust degree of the supplier to the investment company remains unchanged ($\alpha_b = 0.6$), and the trust degree of the investment company to the supplier α_a increases from 0.6 to 0.9 (line c, line e), there is an obvious acceleration of the evolution speed of the investment company to the active cooperation strategy. For suppliers, when the trust degree of suppliers to investment companies remains unchanged ($\alpha_b = 0.6$) and the trust degree of investment companies to suppliers α_a increases from 0.3 to 0.9 (line a, line c, line e), the evolution speed of investment companies toward active cooperation is not obvious. Therefore, when the trust degree of the supplier to the investment company remains unchanged ($\alpha_b = 0.6$), and the trust degree of the investment company to the supplier α_a increases from 0.3 to 0.9 (line a, line c, line e), the cooperation strategy of the investment company and the supplier is actively stimulated. Moreover, the active incentive effect on the cooperation strategy of investment companies is more significant.

(III) When the degree of trust between the investment company and the supplier is the same ($\alpha_a = \alpha_b$), it is explored that the cooperation strategy of the investment company and the supplier is affected by the initial cooperation willingness. Three situations ($\alpha_a = \alpha_b = 0$, $\alpha_a = \alpha_b = 0.5$, $\alpha_a = \alpha_b = 1$) are set when the trust degree between the investment company and the supplier is the same. Suppose that the initial cooperation willingness between the investment company and the supplier is $x = y = 0.3$ (representing low initial cooperation willingness) or $x = y = 0.7$ (representing high initial cooperation willingness). The evolution results of cooperation strategies of both parties are shown in Figure 7.

As can be seen from Figure 7, when the investment company and the supplier completely distrust each other ($\alpha_a = \alpha_b = 0$), the cooperation strategies of the investment company and the supplier all evolve toward negative cooperation (line a, line b, line c, line d). However, by comparing the evolutionary results with high initial cooperation willingness ($x = y = 0.7$; line a, line b) and low initial cooperation willingness $x = y = 0.3$; line c, line d), it can be seen that when the initial cooperation willingness of the investment company and the supplier is high, the rate of evolution toward the negative cooperative strategy decreased (line c, line d). When the degree of mutual trust between the investment company and the supplier is 0.5 ($\alpha_a = \alpha_b = 0.5$), the cooperation strategies of the investment company and the supplier all evolve toward active cooperation (line i, line j, line k, line l). However, by comparing the evolutionary results with high initial cooperation willingness ($x = y = 0.7$; line k, line l) and low initial cooperation willingness ($x = y = 0.3$; line i, line j), it can be seen that when the initial willingness to cooperate is high, the investment company and the supplier accelerate the evolution to the active cooperation strategy (line k, line l). When the investment company and supplier fully trust each other ($\alpha_a = \alpha_b = 1$), the cooperation strategies of the investment company and supplier rapidly evolve toward active cooperation (line e, line f, line g, line h). Compared with the evolutionary results with higher initial willingness to cooperate ($x = y = 0.7$; line e, line f) and lower initial willingness to cooperate ($x = y = 0.3$ line g, line h), it can be seen that when the initial willingness to cooperate is high and that the investment company and supplier will accelerate the evolution toward the active cooperation strategy (line g, line h).

4.2.2. Influence of Moral Hazard Coefficient on Evolutionary Strategies of Both Sides of the Game

Since moral hazard occurs when one party chooses an active cooperation strategy while the other party has speculative behavior, two sets of simulation values are set when simulating the influence of investment company and supplier strategy caused by the change of the moral hazard coefficient. (I) When the initial willingness of the investment company is active cooperation and the supplier has speculative behavior, the simulation parameter value is set as $l_a = 0$, $l_b = 0.3$ or $l_b = 0.6$, or $l_b = 0.9$; the initial willingness of the investment company is $x = 0.6$; and the initial willingness of the supplier is $y = 0.3$. (II) When the initial willingness of the supplier is to cooperate actively, and there is speculation behavior in the investment company, the simulation parameter value is set as $l_b = 0$, $l_a = 0.3$ or $l_a = 0.6$, or $l_a = 0.9$; the initial willingness of the investment company is $x = 0.3$; and the initial willingness of the supplier is $y = 0.6$. The simulation results are shown in Figure 8.

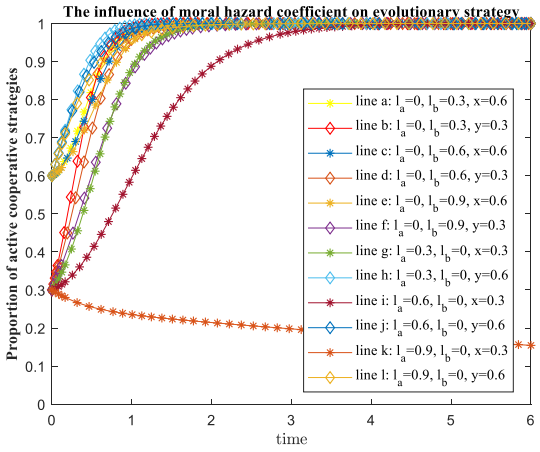

Figure 8. Influence of moral hazard coefficient on evolutionary results.

(I) When the initial willingness of the investment company is active cooperation ($x = 0.6$, $l_a = 0$), as the moral hazard coefficient of the supplier increases from 0.3 to 0.9, the final evolution result of both parties is active cooperation strategy (line a, line b, line c, line d, line e, line f). Since the initial cooperation willingness of the investment company is active cooperation ($x = 0.6$), its evolution speed does not change significantly (line a, line c, line e). Due to the low initial cooperation willingness of suppliers ($y = 0.3$) and the increasing moral hazard coefficient of suppliers (l_b increases from 0.3 to 0.9), the speed of suppliers choosing active cooperation decreases significantly (line b, line d, line f). It shows that when the initial willingness of the investment company is to cooperate actively, the moral hazard coefficient of the supplier increases, which has little influence on the cooperation evolution process of the investment company, and has a negative incentive influence on the cooperation evolution process of the supplier. (II) When the initial willingness of the supplier is active cooperation ($y = 0.6$, $l_b = 0$), as the moral hazard coefficient of the investment company increases from 0.3 to 0.9, due to the high initial willingness of the supplier to cooperate ($y = 0.6$), suppliers maintain an active cooperation strategy (line h, line j, line l) and the change of evolution speed is not obvious. On the other hand, if the initial cooperation willingness of investment companies is low ($x = 0.3$), influenced by the increase in their own moral hazard coefficient (l_a increases from 0 to 0.6), the evolution speed to the active cooperation strategy decreases significantly (line g, line i). Once the moral hazard coefficient of investment companies increases to a certain value, investment companies will evolve toward opportunistic behavior (line k). This indicates that when the initial cooperation willingness of the suppliers is active cooperation, the increase in the moral hazard coefficient of the investment company has little influence on the cooperation evolution process of the suppliers but has a significant negative incentive effect on the cooperation evolution process of the investment company itself. It also indicates that there

is a moral hazard coefficient of the investment company between 0.6 and 0.9, which is the critical value of moral hazard coefficient when investment companies transform from active cooperation strategy to opportunistic behavior.

4.2.3. Influence of Information Asymmetry Coefficient on Evolutionary Strategies of Both Sides of the Game

According to the above simulation parameters of trust degree and moral hazard coefficient and to the relation of information asymmetry coefficient, suppose that the information asymmetry coefficient of an investment company and supplier is (I) $K_a = 0.8$, $K_b = 0.2$; (II) $K_a = 0.2$, $K_b = 0.8$; (III) $K_a = 0.5$, $K_b = 0.5$; (IV) $K_a = 0.2$, $K_b = 0.2$; and (V) $K_a = 0.8$, $K_b = 0.8$; where, $K_i = 0.2$ represents low information asymmetry, and $K_i = 0.8$ represents high information asymmetry. Assuming that the initial cooperation willingness of both parties is (0.5,0.5), the simulation results are shown in Figure 9.

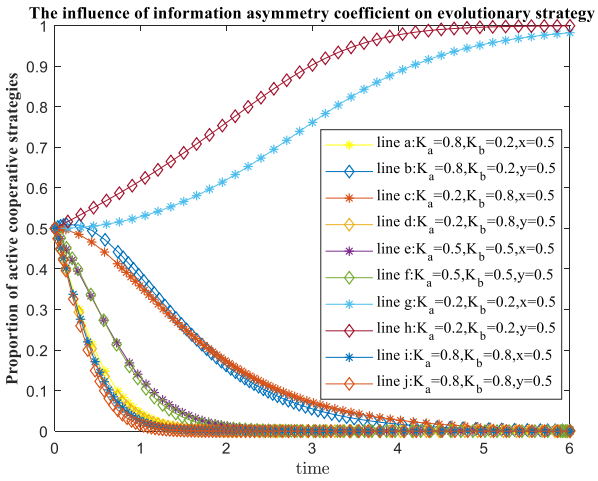

Figure 9. Influence of information asymmetry coefficient on evolution results.

Obviously, only when the information asymmetry coefficient of investment company and supplier is at a low level ($K_a = 0.2$, $K_b = 0.2$), the cooperation strategy of both parties will evolve toward active cooperation (line g, line h). When one party has high information asymmetry ($K_i = 0.8$), the cooperation strategy of both parties will evolve toward the direction of negative cooperation (line a, line b, line c, line d, line e, line f, line i, line j). Among them, when both the investment company and the supplier are in a state of high information asymmetry ($K_a = 0.8$, $K_b = 0.8$), the two sides evolve toward the negative cooperation strategy at the fastest speed (line i, line j). When one party is in a state of high information asymmetry, and the other party is in a state of low information asymmetry ($K_a = 0.8$, $K_b = 0.2$ or $K_a = 0.2$, or $K_b = 0.8$), the speed of the negative cooperation strategy evolution with high information asymmetry is much higher than that of low information asymmetry (line a, line b, line c, line d). Therefore, only when the information asymmetry coefficient between investment companies and suppliers is at a low level ($K_a = 0.2$, $K_b = 0.2$), the cooperation between the two sides will evolve toward an active strategy (line g, line h). With the increase in the information asymmetry coefficient, the cooperation strategy of investment companies and suppliers gradually changes from an active cooperation state to a negative cooperation state. The change of information asymmetry coefficient is highly sensitive to the influence of the evolutionary strategy of both sides and has a significant negative incentive effect on the trust evolution of investment companies and suppliers.

Based on the analysis conducted, (I) the examination of trust degree unfolds as follows: (i) Asymmetry in trust degree can accelerate the evolution of investment companies and suppliers toward active cooperation strategies, acting as a positive incentive for their cooperation in PPP projects. (ii) When the investment company's trust degree in the supplier remains constant while the supplier's trust degree in the investment company increases, the

evolution of both parties toward active cooperation strategies can be expedited, with a more pronounced positive incentive effect on the supplier's cooperation strategy. (iii) Similarly, when the supplier's trust degree in the investment company remains constant while the investment company's trust degree in the supplier increases, it leads to actively incentivized cooperation strategies for both parties, with a more prominent positive incentive effect on the investment company's cooperation strategy. (iv) In the case of mutual trust degree between the investment company and the supplier, coupled with a high initial willingness to cooperate, the speed of evolution toward active cooperation strategies is enhanced, while the speed of evolution toward negative cooperation strategies is diminished. However, the initial willingness to cooperate does not alter the choice of cooperation strategy by the investment company and the supplier.

(II) The examination of the moral hazard coefficient unfolds as follows: (i) When the investment company has an initial willingness to actively cooperate, an increase in the moral hazard coefficient of the supplier has minimal influence on the cooperation evolution outcome of the investment company. However, it does have a negative incentive effect on the cooperation evolution outcome of the supplier itself. (ii) Similarly, when the suppliers have an initial willingness to engage in active cooperation, an increase in the moral hazard coefficient of the investment company has little impact on the cooperation evolution outcome of the suppliers. However, it significantly affects the cooperation evolution outcome of the investment company itself, serving as a notable negative incentive. Overall, the increase in the moral hazard coefficient of the investment company exerts a more substantial influence on the cooperation strategy of the entire system compared to that of the supplier.

(III) The examination of the coefficient of information asymmetry unfolds as follows: (i) It is observed that the evolution toward active cooperation strategy between the investment company and the supplier can only occur when the degree of information asymmetry is kept at a low level. (ii) The variation in the information asymmetry coefficient significantly influences the cooperation strategy between investment companies and suppliers. Specifically, an increase in the information asymmetry coefficient negatively affects the incentive for cooperation strategy evolution.

4.3. Discussion

This paper takes into account the complexity and dynamics of the supply chain in PPP projects, establishes a trust evolution game model for the PPP supply chain, and analyzes the crucial factors influencing the partnership among the main entities in the PPP supply chain. The model is solved using the Jacobian matrix, and the stability of the equilibrium solution is analyzed. The potential scenarios are classified to examine the conditions for trust evolution in the PPP supply chain under different circumstances. Matlab2010b is utilized to simulate the evolutionary trajectory of investment companies and suppliers in various scenarios, and the trust level, moral hazard coefficient, and information asymmetry coefficient between investment companies and suppliers are analyzed. The findings reveal that (i) based on the replication dynamic equation and the evolutionary trajectory of the investment company and the supplier's returns, it is evident that the strategic choices of both parties in the game are not stable but rather are influenced by various factors. (ii) A certain level of trust asymmetry between the investment company and the supplier can facilitate the evolution toward the active cooperation strategy. Increased trust expedites the transition to the active strategy. When the initial cooperation willingness of the investment company and the supplier is high, it accelerates the evolutionary process of both parties. However, the cooperation strategy of the investment company and the supplier is more influenced by the degree of trust in the cooperative process rather than the initial cooperation willingness. (iii) The rise in the moral hazard coefficient significantly discourages cooperation strategies among investment companies and suppliers. Specifically, the increase in the moral hazard coefficient of investment companies has a much larger impact on the entire system's cooperation strategies compared to the increase in the moral hazard coefficient of

suppliers. (iv) Information asymmetry strongly hampers the cooperation strategy between investment companies and suppliers. Only when the information asymmetry coefficient between the two parties is low can they evolve toward an active cooperation strategy.

The presence of a certain level of trust asymmetry during the cooperation process fosters a positive monitoring atmosphere, enhances the team's self-management capabilities, and improves overall team performance. This viewpoint is supported by the study on asymmetric trust behavior in construction projects conducted by Li et al. [47]. Enhancing mutual trust between investment companies and suppliers encourages both parties to opt for active cooperation strategies. Previous research has also highlighted that improving trust in cooperation facilitates better communication, reduces transaction costs, and promotes smooth collaboration [48,49], which aligns with the findings of this study. In the cooperation process, the strategy selection of investment companies and suppliers is less influenced by the initial willingness to cooperate. This may be due to the fact that partners' strategies are influenced by various dynamic factors throughout the implementation of PPP projects.

The moral hazard coefficient reflects the speculative behavior, wherein one party of the supply chain opts for active cooperation while the other party chooses negative cooperation. When the moral hazard coefficient is high, if one party of the cooperative entity chooses a positive cooperation strategy, the other party may engage in opportunistic behavior, leading to a negative market environment [50]. This study further concludes that an increase in the moral hazard coefficient of investment companies has a stronger negative impact on partnerships within the PPP supply chain. The primary reason behind this is the inconsistent cooperation status between the investment company and the supplier, with the investment company often occupying a dominant position while the supplier remains in a passive state. Previous research has also indicated that the market institutional environment and imbalanced power distribution indirectly decrease the level of trust between partners, thereby impeding the smooth implementation of projects [45,51]. Therefore, it is crucial for the government to strengthen the supervision of moral hazard behaviors exhibited by investment companies, penalize opportunistic behaviors, reduce the status inequality between investment companies and suppliers, enhance incentives for active cooperation, improve the reward and punishment mechanism, and foster a conducive market environment.

Effective communication and positive interaction play a crucial role in fostering trust formation and maintaining trust relationships by facilitating partner interactions [52]. Improving information transparency can mitigate information asymmetry in contracting relationships and enhance trust [53–55]. In this study, the information asymmetry coefficient significantly influences the strategy selection of investment companies and suppliers within the PPP supply chain. Only when the degree of information asymmetry between investment companies and suppliers is low, can both parties evolve toward an active cooperation strategy. This finding aligns with previous research conclusions. Investment companies and suppliers should recognize the gravity of highly asymmetric information and establish effective communication and coordination channels to strengthen cooperation, reduce the information asymmetry coefficient, and establish a trusted platform for the PPP supply chain. By leveraging technologies, such as big data, digital twinning, and blockchain, an information platform can be developed to enable real-time sharing of financial, scheduling, quality, and other relevant information, thereby reducing information asymmetry between investment companies and suppliers. This, in turn, facilitates mutual supervision and helps mitigate opportunistic behaviors during the construction, operation, and maintenance processes, ultimately leading to higher cooperation satisfaction and improved quality and efficiency of PPP supply chain projects.

Existing studies have primarily focused on the importance of trust in the cooperation between the government and social capital within PPP projects, with limited research on supply chain trust mainly centered around trust levels [56] and reward and punishment measures [57]. The impact of the moral hazard coefficient and information asymmetry

coefficient on trust in cooperative relationships has not been adequately addressed [58]. Moreover, there is a lack of research on the evolution mechanism of trust in PPP supply chains. This study conducts a comprehensive analysis of the impact of factors, including the information asymmetry coefficient, trust degree, and moral hazard coefficient, on the cooperative strategy adopted by both parties. By developing a trust evolution game model within the context of the PPP supply chain, the research aims to make a significant contribution toward improving the effectiveness of PPP supply chain project contracts. Additionally, the study seeks to protect the interests of all stakeholders involved and ensure the delivery of superior project products and operational services.

5. Conclusions

The PPP supply chain includes many participants. The project scopes within the PPP supply chain are extensive. The implementation periods in the PPP supply chain are prolonged. The implementation process in the PPP supply chain is dynamic. Trust plays a crucial role in fostering effective cooperation between investment companies and suppliers in the PPP supply chain. It plays a vital role in facilitating contract performance, safeguarding the interests of all stakeholders, and ensuring the delivery of high-quality project products and operational services. In this study, we construct an income matrix and replication dynamic equation to examine the cooperation between investment companies and suppliers in PPP projects. Furthermore, we employ the Jacobian matrix to solve the model, analyze the stability of the equilibrium solution, and explore the evolution path of cooperation strategies between investment companies and suppliers in various scenarios. Through numerical simulation analysis of key influencing factors, this study explores the impact of parameter changes on the evolution of cooperation strategies.

The research results show that (i) a certain degree of trust asymmetry between investment companies and suppliers can accelerate the evolution of both parties to the active cooperation strategy. Therefore, a certain degree of trust asymmetry has an active incentive effect on the active cooperation strategy between investment companies and suppliers; (ii) If the trust degree of one party in the investment company or supplier remains unchanged, and the trust degree of the other party increases, the party with the increased trust degree will quickly choose the active cooperation strategy. (iii) When the trust degree of the investment company and the supplier is consistent, if the initial willingness of the investment company and the supplier to cooperate is high, it will accelerate the evolution speed of the two sides toward the active cooperation strategy or reduce the evolution speed of the two sides toward the negative cooperation strategy, but the cooperation strategy of the two sides is less affected by the initial cooperation willingness. (iv) The negative impact of the moral hazard coefficient on cooperation strategy is only reflected in the side with the change in the moral hazard coefficient itself, and the negative impact of the increase in moral hazard coefficient of the investment company on the whole system is greater than that of the increase in the moral hazard coefficient of the supplier on the whole system. (v) The information asymmetry coefficient has a significant negative impact on the cooperation strategies of investment companies and suppliers. Only when the information asymmetry coefficient is at a low level can both parties evolve toward an active cooperation strategy.

The main contributions of this study are as follows: (i) Examining the evolution mechanism of the PPP trust from the perspective of the supply chain in order to understand the fundamental dynamic relationship among PPP stakeholders, and (ii) analyzing the evolution patterns of trust within the PPP network from three dimensions—trust degree, moral hazard coefficient, and information asymmetry coefficient. This approach enhances the reliability and robustness of the research findings.

This article discusses management implications from three aspects: platform construction, improvement of management system, and communication and exchange.

The government has the opportunity to establish a robust PPP supply chain trust platform that harnesses advanced technologies like big data, digital twins, and blockchain.

This platform would serve as an information hub, enabling real-time sharing of financial, progress, and quality information. By bridging the information gap between investment companies and suppliers, it would create a favorable environment for mutual supervision, discouraging opportunistic behavior during the construction and operation phases. Consequently, this would foster trust between investment companies and suppliers, leading to higher levels of collaborative benefits. Moreover, the government could develop a trust rating system for PPP project investment companies and suppliers. This rating system would serve as a basis for restrictions on companies with lower trust ratings, preventing them from participating in PPP project investments and construction. This measure would effectively discourage opportunistic behavior during project cooperation. Furthermore, trust ratings could be incorporated as a primary assessment criterion during the bidding process, fostering a culture of trust and establishing a robust trust system among investment companies and suppliers in the supply chain.

The government and relevant institutions should strengthen the supervision of supply chain members through the establishment of a robust incentive mechanism. To begin with, improving the performance supervision mechanism of PPP projects by involving third-party regulatory agencies and increasing public participation in regulatory mechanisms is crucial. This approach will effectively reduce the costs associated with opportunistic behaviors, particularly in terms of regulating supplier opportunistic behaviors. Moreover, investment companies and suppliers that consistently fulfill their contractual obligations should be rewarded by the government and relevant institutions, who should also provide appropriate compensation. This will foster the establishment and maintenance of trust between the two parties. By implementing a well-designed incentive mechanism, the interests of the performing party can be safeguarded, the behavior of speculators can be regulated, and a conducive environment of trust can be fostered.

The trading environment is influenced by various macro- and microfactors, making it crucial to establish and maintain trust for smooth project operation. Unlike mandatory constraints under contract mechanisms, the parties involved in cooperation must handle trust relationships from different perspectives. Therefore, investment companies and suppliers must prioritize communication and trust-building in the early stages of the project. It is essential for investment companies and suppliers to maintain timely communication and strengthen mutual trust at different stages of the construction project to prevent neglect, which could potentially lead to project failure. Additionally, investment companies and suppliers should fully recognize the advantages of a solid trust relationship in enhancing cooperation and reducing transaction costs, thereby providing a significant advantage for achieving project success.

However, this paper has certain limitations. (i) The PPP supply chain encompasses numerous stakeholders and a diverse range of businesses. The focus of this study is solely on the evolution mechanism of trust between investment companies and suppliers. (ii) There are various ways for the government to intervene in cooperation between investment companies and suppliers. This paper only presents the government intervention behavior from the perspective of reward and punishment, but cannot fully reflect the government behavior in the actual project implementation process. In order to comprehensively promote the high-quality cooperation of PPP supply chain, there is still a large research space for this topic.

Author Contributions: Conceptualization, H.L.; methodology, Y.Z.; writing—original draft preparation, Y.C. and M.L.; writing—review and editing, W.Z. and L.S. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Social Science Foundation of China under Grant [NO.22FGLB082].

Data Availability Statement: The study data can be requested from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Rezahoseini, A.; Noori, S.; Ghannadpour, S. Integrated scheduling of suppliers and multi-project activities for green construction supply chains under uncertainty. *Autom. Constr.* **2021**, *122*, 103485. [CrossRef]
2. Liao, L.; Yang, C.; Quan, L. Construction supply chain management: A systematic literature review and future development. *J. Clean. Prod.* **2023**, *382*, 135230. [CrossRef]
3. Li, H.; Wang, F.; Wang, L.; Su, L.; Zhang, C. The Stochastic Evolution Game of Knowledge Sharing in the Infrastructure PPP Supply Chain Network. *Complexity* **2020**, *2020*, 8858845. [CrossRef]
4. Heffernan, T. Trust formation in cross-cultural business-to-business relationships. *Qual. Mark. Res.* **2004**, *7*, 114–125. [CrossRef]
5. Claro, D.; Hagelaar, G.; Omta, O. The Determinants of Relational Governance and Performance. *Ind. Mark. Manag.* **2003**, *32*, 703–716. [CrossRef]
6. Yoon, J.; Moon, J. The moderating effect of buyer purchasing strategy on the relationship between supplier transaction-specific investment and supplier firm performance. *J. Bus. Res.* **2017**, *99*, 516–523. [CrossRef]
7. Ryu, S.; Park, J.E.; Min, S. Factors of Determining Long-Term Orientation in Interfirm Relationships. *J. Bus. Res.* **2007**, *60*, 1225–1233. [CrossRef]
8. Li, Z.; Sheng, Z.; Meng, Q. Analysis on connotation and key elements of engineering supply chain. *Oper. Res. Manag.* **2017**, *26*, 82–88.
9. Xue, X.; Li, X.; Shen, G.; Wang, Y. An agent-based framework for supply chain coordination in construction. *Autom. Constr.* **2005**, *14*, 413–430. [CrossRef]
10. Koskela, L. Application of the New Production Philosophy to Construction. 1992. Available online: https://stacks.stanford.edu/file/druid:kh328xt3298/TR072.pdf (accessed on 15 January 2023).
11. Hatmoko, J.; Scott, S. Simulating the impact of supply chain management practice on the performance of medium-sized building projects. *Constr. Manag. Econ.* **2010**, *28*, 35–49. [CrossRef]
12. Alderman, N.; Ivory, C. Partnering in major contracts: Paradox and metaphor. *Int. J. Proj. Manag.* **2007**, *25*, 386–393. [CrossRef]
13. Akintoye, A.; Mcintosh, G.; Fitzgerald, E. A Survey of Supply Chain Collaboration and Management in the UK Construction Industry. *Eur. J. Purch. Supply Manag.* **2000**, *6*, 159–168. [CrossRef]
14. Mangla, S.; Kumar, P.; Barua, M. Risk analysis in green supply chain using fuzzy AHP approach: A case study. *Resour. Conserv. Recycl.* **2015**, *104*, 375–390. [CrossRef]
15. Baiden, B.K.; Price, A.; Dainty, A. The extent of team integration within construction projects. *Int. J. Proj. Manag.* **2006**, *24*, 13–23. [CrossRef]
16. Nicolini, D.; Holti, R.; Smalley, M. Integrating project activities: The theory and practice of managing the supply chain through clusters. *Constr. Manag. Econ.* **2001**, *19*, 37–47. [CrossRef]
17. Shi, Y.; Ma, H.; Xiao, T. Research on the formation and evolution of trust relationship among supply chain members. *Syst. Sci. Math.* **2011**, *31*, 1386–1394.
18. Xia, M.; Zhao, L.; Zhao, L.; Feng, Q. The impact of blockchain technology applicability on prefabricated building supply chain performance, The mediating role of trust relationships. *Constr. Econ.* **2022**, *43*, 864–879. [CrossRef]
19. Jagtap, M.; Kamble, S. An empirical assessment of relational contracting model for supply chain of construction projects. *Int. J. Proj. Manag.* **2019**, *13*, 1537–1560. [CrossRef]
20. Mora-monge, C.; Quesada, G.; Gonzalez, M.; Davis, J. Trust, power and supply chain integration in Web-enabled supply chains. *Supply Chain Manag.* **2019**, *24*, 524–539. [CrossRef]
21. Zhang, M.; Huo, B. The impact of dependence and trust on supply chain integration. *Int. J. Phys. Distrib. Logist. Manag.* **2013**, *43*, 544–563. [CrossRef]
22. Tsanos, C.; Zografos, K. The Effects of Behavioural Supply Chain Relationship Antecedents on Integration and Performance. *Supply Chain Manag.* **2016**, *21*, 678–693. [CrossRef]
23. Terpend, R.; Ashenbaum, B. The Intersection of Power, Trust and Supplier Network Size: Implications for Supplier Performance. *J. Supply Chain Manag.* **2012**, *48*, 52–77. [CrossRef]
24. Villena, V.; Revilla, E.; Choi, T. The Dark Side of Buyer-Supplier Relationships: A Social Capital Perspective. *J. Oper. Manag.* **2011**, *29*, 561–576. [CrossRef]
25. Saleh, M.; Ali, M.Y.; Andaleeb, S. Explaining industrial importers' commitment from an emerging market perspective: Theoretical and managerial insights. *J. Bus. Ind. Mark.* **2014**, *29*, 45–62. [CrossRef]
26. Saleh, M.; Ali, M.Y.; Mavondo, F. Drivers of importer trust and commitment: Evidence from a developing country. *J. Bus. Res.* **2014**, *67*, 2523–2530. [CrossRef]
27. Talay, M.; Akdeniz, B. In time we trust? The effects of duration on the dynamics of trust-building processes in inter-organizational relationships. *Strat. Manag. Rev.* **2014**, *8*, 77–90.
28. Kwon, I.-W.; Suh, T. Factors Affecting the Level of Trust and Commitment in Supply Chain Management. *J. Supply Chain Manag.* **2004**, *40*, 4–14. [CrossRef]
29. Hausman, A.; Johnston, W. The impact of coercive and non-coercive forms of influence on trust, commitment, and compliance in supply chains. *Ind. Mark. Manag.* **2010**, *39*, 519–526. [CrossRef]
30. Ren, Z.; Liu, Y. Research on trust transmission mechanism of PPP projects based on Evolutionary game. *Local Financ. Study* **2017**, *156*, 33–41.

31. Du, Y.; Wang, Y. Research on Dynamic Evolution of trust in PPP projects. *Constr. Econ.* **2012**, *358*, 28–33. [CrossRef]
32. Guo, G.; Zhao, F.; Zhuang, R. A study on the bilateral Moral Hazard of PPP projects in China. *Ind. Econ. Rev.* **2022**, *13*, 147–160. [CrossRef]
33. Wang, X.; Yuan, S.; Lin, Z.; Zhao, J.; Qin, Y. Research on Incentive Mechanism of PPP projects under double information asymmetry considering equity preference. *Chin. Manag. Sci.* **2021**, *29*, 107–120. [CrossRef]
34. Friedman, D. On economic application of evolutionary game theory. *J. Evol. Econ.* **1998**, *8*, 15–43. [CrossRef]
35. Friedman, D. Evolutionary Game in Economics. *Econometrica* **1991**, *59*, 637–666. [CrossRef]
36. Newton, J. Evolutionary Game Theory: A Renaissance. *Games* **2018**, *9*, 31. [CrossRef]
37. Hao, C.; Du, Q.; Huang, Y.; Shao, L. Evolutionary Game Analysis on Knowledge-Sharing Behavior in the Construction Supply Chain. *Sustainability* **2019**, *11*, 5319. [CrossRef]
38. Kang, K.; Zhao, Y.; Zhang, J.; Chen, Q. Evolutionary game theoretic analysis on low-carbon strategy for supply chain enterprises. *J. Clean. Prod.* **2019**, *230*, 981–994. [CrossRef]
39. Sun, R.; HE, D.; Su, H. Evolutionary Game Analysis of Blockchain Technology Preventing Supply Chain Financial Risks. *J. Theor.* **2021**, *16*, 2824–2842. [CrossRef]
40. Li, C.; Zhang, F.; Cao, C.; Liu, Y.; Qu, T. Organizational coordination in sustainable humanitarian supply chain: An evolutionary game approach. *J. Clean. Prod.* **2019**, *219*, 291–303. [CrossRef]
41. Vosooghidizaji, M.; Taghipour, A.; Canel-depitre, B. Coordinating corporate social responsibility in a two-level supply chain under bilateral information asymmetry. *J. Clean. Prod.* **2022**, *364*, 132627. [CrossRef]
42. Pan, L.; Chen, X.; Zhao, L.; Xiao, A. Does Information Asymmetry Impact Sub-Regions' Cooperation of Regional Water Resource Allocation? *Int. J. Environ. Res. Public Health* **2019**, *16*, 4292. [CrossRef] [PubMed]
43. Gaudeul, A.; Keser, C.; Müller, S. The Evolution of Morals under Indirect Reciprocity. *Games Econ. Behav.* **2021**, *126*, 251–277. [CrossRef]
44. Liu, J.; Yu, C.; Li, C.; Han, J. Cooperation or Conflict in Doctor-Patient Relationship? An Analysis From the Perspective of Evolutionary Game. *IEEE Access* **2020**, *8*, 42898–42908. [CrossRef]
45. Nie, X.; Feng, K.; Zhao, G.; Fan, T.; Wang, S. The Evolutionary Game of Trust in Public-Private Partnership Project Networks. *Math. Probl. Eng.* **2021**, *2021*, 5514708. [CrossRef]
46. Dai, Y.; Lu, P. When does inferring reputation probability countervail temptation in cooperative behaviors for the prisoners' dilemma game? *Chaos Soliton Fract.* **2015**, *78*, 238–244. [CrossRef]
47. Li, Y.; He, N.; Li, H.; Liu, Z.; Qi, J. Influencing factors on inter-organizational trust asymmetry behavior in construction projects. *Eng. Archit. Eng.* **2021**, *28*, 308–331. [CrossRef]
48. Meng, X. The effect of relationship management on project performance in construction. *Int. J. Proj. Manag.* **2012**, *30*, 188–198. [CrossRef]
49. Cheung, S.; Yiu, T.; Lam, M. Interweaving Trust and Communication with Project Performance. *J. Constr. Eng. Manag.* **2013**, *139*, 941–950. [CrossRef]
50. Dastyar, H.; Rippel, D.; Pannek, J.; Thoben, K.; Freitag, M. A Numerical Study on the Effects of Trust in Supplier Development. *Processes* **2020**, *2020*, 300. [CrossRef]
51. Argyres, N. Contract design capabilities and contract performance by high technology firms: Implications for the roles of lawyers, managers and engineers. In Proceedings of the 8th Annual ISNIE Conference, Tucson, AZ, USA, 30 September–3 October 2004.
52. Caniëls, M.; Vos, F.; Schiele, H.; Pulles, N. The effects of balanced and asymmetric dependence on supplier satisfaction: Identifying positive effects of dependency. *J. Purch. Supply Manag.* **2017**, *24*, 343–351. [CrossRef]
53. Nestle, V.; Täube, F.; Heidenreich, S.; Bogers, M. Establishing open innovation culture in cluster initiatives: The role of trust and information asymmetry. *Technol. Forecast. Soc. Chang.* **2019**, *146*, 563–572. [CrossRef]
54. Forsythe, P.; Sankaran, S.; Biesenthal, C. How Far Can BIM Reduce Information Asymmetry in the Australian Construction Context? *Proj. Manag. J.* **2015**, *46*, 75–87. [CrossRef]
55. Foscht, T.; Lin, Y.-T.; Eisingerich, A. Blinds up or down?: The influence of transparency, future orientation, and CSR on sustainable and responsible behavior. *Eur. J. Mark.* **2018**, *52*, 476–498. [CrossRef]
56. Chen, X. Research on the Incentive Mechanism of the Pension Service Supply Chain under Asymmetric Information. *Math. Probl. Eng.* **2021**, *2021*, 5219420. [CrossRef]
57. Chen, Y.; Sun, L. Trust strategy simulation of corporation–NPO cross alliance using evolutionary game theory. *Kybernetes* **2017**, *46*, 450–465. [CrossRef]
58. Gunnar , J.L.; Marian, G.C.B.; Mladen, R. Key stakeholders' perspectives on the ideal partnering culture in construction projects. *Front. Eng. Manag.* **2022**, *9*, 312–325. [CrossRef]