

Game Analysis of Private Equity Investment Funds and Financing Enterprises

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Abstract

The relevant entities involved in private equity investment funds include investors, private equity investment funds, and financing enterprises. With the policy background of establishing a multi-level financial market, there exists significant risks in the operation of PE funds at all stages, it is necessary to introduce the design of a series of transaction structures to implement good risk control and capital appreciation. Based on the current situation of private equity investment funds in the investment field of China, this paper mainly discusses about the coordination between financing parties and private equity investment funds from the perspective of game theory, it constructs a game model between private equity investment funds and financing enterprises from the perspective of transaction structure, proposes phased investment, incentives and internal control, signing gambling agreements to provide effective trading strategies for both investment and financing parties, and to protect the rights and interests of investors and ensure the stability of the national financial system.

Keywords

Private Equity, Financing Enterprise, Game Theory, Transaction Structure.

1. Introduction

As a production of the combination of financial innovation and industrial innovation, private equity(PE) funds play an important role in providing a valuable capital and sustainable development for start-up companies, spawning new industries, accelerating the upgrade of industrial structure and consumption level, and creating more employment opportunities. Due to the characteristics of non-disclosure and non-listing, the trading process and details of private equity investments are rarely disclosed publicly, and this uncertainty makes it difficult for investors to make investment decisions, and the management of private equity investment funds also poses significant risks. In addition, the dual principal-agent game relationship and the long-term and poor liquidity characteristics of the investment cycle make it more difficult to control risks.

There exist a number of researches on the strategies and methodologies of private equity based on game theory and contract theory [1-10]. Cabels[1] studied the cooperative game relationship between PE funds and financing enterprises. By establishing a prisoner's dilemma model for both parties, it was found that full cooperation and trust between both parties are the core factors to ensure the operation of the enterprise and the profitability of private equity investment. Dessi [2] believes that in the contract design of transaction structures, both investment and financing parties should aim to incentivize the financing enterprise and both parties to make balanced decisions at all stages, which is also the original intention of studying control rights and cash allocation. Yitshaki [3] used the research method of interview and

communication to collect relevant data, and found that conflicts are inevitable in the negotiation process between investment and financing parties. As an inherent attribute, both parties should actively face and propose reasonable solutions, such as setting win-win contract terms, constraints and incentive mechanisms, to promote cooperation and communication, and to address conflicts to maximize the interests of both parties. Sandeepd[4] found that in the early stages of financing enterprise projects, there are many uncertainties in proving themselves in the market. At this time, adopting a phased investment approach is an effective measure to protect their rights and prevent risks.

Zhao[5] studied the establishment of four game models under the assumption of a given financing enterprise's effort cost, random probability distribution, and output to return ratio. They proposed possible strategic ideas and choices for both investment and financing parties in an environment with significant uncertainty in risk. Xu [6] studied the two-party game behavior between financing enterprises and PE investments. He first established a three-stage basic investment game model, and then established two models, non cooperative game and cooperative game, for the third stage of the game. Ma[7] used evolutionary game theory to study the mechanism and existing problems of adverse selection in the game process between financing enterprises and venture capital. Zheng [8] studied the interaction mechanism and strategy selection of PE investment under limited and investor bounded rationality conditions. They also used evolutionary game theory methods to verify whether the supervisory and incentive effects of punishment mechanisms are effective for different financing investors, and how to make strategic decisions and provide relevant suggestions. Li[9] established game models for different investment stages of PE based on game theory, and studied the supply and demand relationship of capital by solving Nash equilibrium under different strategic game models. Jiang [10] established three basic game models for the three stages of private equity investment mentioned above, and studied the relationship between the two parties in the game. Proposing the individual benefits of entrepreneurial entrepreneurs is crucial for ensuring the effective investment process.

At present, a large number of studies on private equity investment funds based on game theory and contract theory, involving various stages of private equity investment, such as project evaluation and exit models, but there are few researches focusing on the relationship between private investment funds and financing enterprises strategies under the view of the design of a series of transaction structures. This article constructs a game model between financing enterprises and private equity investment funds, and studies relevant strategies under the view of the design of a series of transaction structures, hoping to implement good risk control and capital appreciation, and to protect the rights and interests of investors and ensure the stability of the national financial system.

2. Preliminary

Game theory is the formal study of decision-making in which economic agents make strategic interactions to produce outcomes to maximize their own utility under certain constraints. According to Zhang [11] and Nisan [12], there exist following basic concepts and theorem:

Definition 1 Given the n -player game $G = \{S_1, \dots, S_n; u_1, \dots, u_n\}$, the strategies $\{S_1^*, \dots, S_n^*\}$ is a Nash equilibrium if, for each player i , s_i^* is player i 's best response to the strategies of the $n-1$ other players

$\{S_1^*, \dots, S_{i-1}^*, S_{i+1}^*, \dots, S_n^*\}$, $u_i(s_i^*, s_{-i}^*) \geq u_i(s_i, s_{-i}^*), \forall s_i \in S_i, \forall i$ for every feasible strategy s_i in S_i , that is, s_i^* solves $\max_{s_i \in S_i} u_i(s_1^*, \dots, s_{i-1}^*, s_i, s_{i+1}^*, \dots, s_n^*), i = 1, 2, \dots, n$.

Definition 2 Given the n -player game $G = \{S_1, \dots, S_n; u_1, \dots, u_n\}$, for each player i , $S_i = \{s_{i1}, \dots, s_{ik}\}$, Then a mixed strategy for player i is a probability distribution $p_i = \{p_{i1}, \dots, p_{ik}\}$, where $k = 1, \dots, K, 0 \leq p_{ik} \leq 1, \sum_i^k p_{ik} = 1$.

Definition 3 Given the n -player game $G = \{S_1, \dots, S_n; u_1, \dots, u_n\}$, the mixed strategies $p^* = \{p_1^*, \dots, p_i^*, \dots, p_n^*\}$ is a Nash equilibrium if $v_i(p_i^*, p_{-i}^*) \geq v_i(p_i, p_{-i}^*), \forall p_i \in \sum_i$ for each player $i=1, 2, \dots, n$.

3. Game Analysis of Coalition-Proof Consensus in Blockchain System

Without loss of generality, there exists a 2-players game, and all players of this game are assumed to be rational and risk neutral, and this is common knowledge, we can represent the Normal form of 2-player complete information static game may as follow:

(1) Player set: defined as $N = \{Pe, Fe\}$, each of them represents a player in game, here Pe means the private equity fund, Fe means the financing enterprise.

(2) Strategy set: The strategies of participant Pe include one-dimensional vectors I, p and s , each the strategy set is $[0, I_h], [0, 1]$ and $[0, s_h]$, and the strategy of the participant Fe is a one-dimensional vector e , and the strategy set is $[0, e_h]$.

(3) Payoff function: The utility of private equity investment funds is the total equity value at the expected exit minus the return on general monetary funds, its utility function is:

$$U_{Pe} = f(I)g(e)I(s)R(I, e, s, m)p - (1 + \theta)I \quad (1)$$

The utility of a financing enterprise is the expected total equity value at the time of fund exit minus the cost of effort, and its utility function is:

$$U_{Fe} = f(I)g(e)I(s)R(I, e, s, m)(1 - p) - C(e) \quad (2)$$

While e represents the effort level of the financing enterprise, it is continuous and $e \geq 0$, and e_h is the upper limit of the effort level; The effort cost of a financing enterprise is $C(e)$ which is an increasing function of the effort level of the financing enterprise, and the marginal effort cost increases, that is $C'(e) > 0$ and $C''(e) > 0$; The investment amount of private equity investment funds is $I (I \geq 0)$ which is also continuous, and I_h is maximum investment limit; The proportion of equity held by private equity investment funds after investment is $p (0 \leq p \leq 1)$, and the equity ratio of the financing enterprise is $1 - p$; The value-added service level of private equity investment funds for financing enterprises is s , and s_h is the highest value-added service level; The development potential or market space of financing enterprises is m ; The value of mature financing enterprises when the fund exits is R , and $R(I, e, s, m)$ is a function of the investment amount of private equity investment funds, the level of effort of financing enterprises, and the development potential of enterprises; $f(I)$, $g(e)$ and $I(s)$ represent the probability of success for a financing enterprise. The function f is an increasing function of I , the function g is an increasing function of e , and the function I is an increasing function of s with diminishing marginal benefits, and $0 \leq f(I), g(e) \leq 1$; The monetary capital return on the investment amount of private equity investment funds is $\theta (\theta > 0)$.

Based on the actual situation, we make the following assumptions about the game model: Private equity investment funds have the same value recognition as financing enterprises, and there are no systemic risks during the development of financing enterprises. Participants do not withdraw midway and hold equity until the agreed period ends; Private equity investment funds cooperate with financing enterprises and sign investment cooperation agreements. The fund decides to invest an amount of I which accounts for p of the company's equity; The effort cost of financing enterprises increases with the increase of effort level, and the marginal effort cost increases. The level of enterprise effort is a function of investment amount and shareholding ratio; The success probability of financing enterprises increases with the increase of their own effort level, shareholding proportion, and the level of value-added services provided by the fund, and the marginal benefits decrease; Due to the significant impact of

regional and industry factors on the government's financial subsidies and tax levels, we will not consider them in this game model.

3.1. Equilibrium Solution of the Game Model

The financing enterprises choose to cooperate with reputable and powerful private equity investment funds to solve the difficulties faced by enterprises in terms of funding and management to some extent. In the game model, financing companies determine their level of effort based on the decisions of private equity investment funds, while private equity investment funds determine the amount of investment and the proportion of equity they hold based on the company's development prospects. Each participant is independent, has controllable decision variables, and influences each other. The condition for maximizing the utility of the participants is that the derivative of the utility function on the decision variable is zero, thus obtaining the game equilibrium solution of the financing enterprise and private equity investment fund.

(1) The Behavior of Private Equity Investment Funds: Let $\frac{\partial U_{Pe}}{\partial I} = 0$, we can obtain the optimal investment amount for private equity investment funds as equation 3:

$$p \left[fgl \frac{\partial R(I, e^*, s^*, m)}{\partial I} + R \frac{\partial fgl}{\partial I} \right] = 1 + \theta \quad (3)$$

while $g'(e^*) = \frac{\partial g(e^*)}{\partial e} \frac{\partial e}{\partial I}$, $l'(s^*) = \frac{\partial l(s^*)}{\partial s} \frac{\partial s}{\partial I}$

Equation 3 indicates that the value of an increase in the investment amount of a private equity investment fund is equal to the marginal return of that value plus the marginal return caused by the probability of success; The proportion of shares p held by private equity investment funds, multiplied by the marginal return on investment amount, is equal to the rate of return on monetary funds to be abandoned $1 + \theta$. From this perspective, the opportunity cost of funds, i.e. the general rate of return, will affect the investment intensity of private equity investment funds in financing enterprises. If the return on investment of market funds generally increases, it is also required that the return on private equity investment should also increase.

(2) The Optimal Share Ratio of Private Equity Investment Funds: Let $\frac{\partial U_{Pe}}{\partial p} = 0$, we can obtain the optimal share ratio of private equity investment funds as equation 4:

$$p \left[R \frac{\partial g(e^*) l(s^*)}{\partial p} + \frac{\partial R}{\partial p} g(e^*) l(s^*) \right] + g(e^*) l(s^*) R = 0 \quad (4)$$

$$\frac{\partial R(I, e^*, s^*, m)}{\partial p} = \frac{\partial R(I, e, s, m)}{\partial e} \frac{\partial e^*}{\partial p} + \frac{\partial R(I, e, s, m)}{\partial s} \frac{\partial s^*}{\partial p}, \frac{\partial g(e^*)}{\partial p} = \frac{\partial g(e)}{\partial e} \frac{\partial e^*}{\partial p}, \frac{\partial l(s^*)}{\partial p} = \frac{\partial l(s)}{\partial s} \frac{\partial s^*}{\partial p}$$

Equation 4 indicate that increasing the equity ratio of a private equity investment fund by one unit will reduce the expected value of the financing enterprise when the fund exits. The proportion of equity held by private equity investment funds multiplied by the value of financing enterprises with reduced unit equity ratio, is equal to the expected total value of the financing enterprise.

(3) The behavior of financing enterprises: Taking the derivative of equation 1 with respect to e and make it equal to 0, we can obtain the conditions for maximizing the utility of financing enterprises as equation 5:

$$(1 - p) f(I) l(s) \left[g'(e) R + \frac{\partial R}{\partial e} g(e) \right] = C'(e) \quad (5)$$

The conditional equations 5 for maximizing the utility of financing enterprises indicate that under the condition of no systemic risk, the optimal strategy of financing enterprises is to multiply the equity ratio $(1-p)$ of the financing enterprise by the value added per unit effort level, which is approximately equal to the marginal cost $C'(e)$ of increasing the effort level of the financing enterprise. The larger the equity ratio $(1-p)$ of the financing enterprise, the greater the level of effort of the enterprise.

By combining equations 3, 4, and 5, the Nash equilibrium solution $(e_{nash}, s_{nash}, p_{nash}, l_{nash})$ of a non cooperative game with the maximum utility of the participants can be obtained.

3.2. Speculative Behavior

When the investment amount of private equity investment funds increases, it directly leads to an increase in the level of effort of financing enterprises. In reality, there is an issue of information asymmetry between private equity investment funds and financing companies, which may lead to speculative behavior. Private equity investment funds may reduce the level of value-added services, and financing companies may also cover up problems that arise during the development process, and may reduce their own level of effort.

The utility function of a financing enterprise is differentiated by e , s , and l , resulting in equation 6:

$$dU_{Fe} = (1-p)f(l)s \left[g(e) \frac{\partial R}{\partial e} + g'(e)R \right] de - C'(e)de + (1-p)f(l)g(e) \left[l'(s)R + C(e) \frac{\partial R}{\partial e} \right] ds + (1-p) \left[fgl \frac{\partial R}{\partial l} + \frac{\partial(fgl)}{\partial l} R \right] dl \quad (6)$$

From equation 5, it can be seen that the first two items to the right of the equal sign in equation 6 are the conditions for the optimal decision of the financing enterprise in a non cooperative game, with a maximum utility of 0. The third and fourth items are both positive, they indicate that an increase in fund investment amount and an improvement in service level will promote the expected value improvement of financing enterprises. Increasing the investment amount and improving the level of value-added services provided by private equity investment funds will increase the expected value of financing enterprises. However, under the premise of maximizing the utility of financing enterprises, there is no incentive for financing enterprises to improve their own level of effort

(2) The utility function of private equity investment funds is differentiated by e , s and l , resulting in equation 7:

$$dU_{Pe} = p \left[\frac{\partial(fgl)}{\partial l} R + fgl \frac{\partial R}{\partial l} \right] dl - (1+\theta)dl + pf(l)s \left[g(e) \frac{\partial R}{\partial e} + g'(e)R \right] de + pf(l)g(e) \left[l'(s)R + l(s) \frac{\partial R}{\partial s} \right] ds \quad (3)$$

According to equation 3, the first two items to the right of the equal sign in equation 7 are the optimal decision conditions for the investment amount of private equity investment funds in non cooperative games, and they are equal to 0 when the utility is maximized., and the last two terms of equations 7 are also positive values. If the financing company improves its own level of effort, the expected returns of private equity investment funds upon exit will also increase. However, under the condition of maximizing the utility of private equity investment funds, there is no incentive to increase the investment amount of the fund.

From the above analysis, it can be seen that there is a positive externality between the investment amount of private equity investment funds, the level of value-added services provided, and the efforts of financing enterprises. When the fund increases its investment amount, the financing enterprise also increases its level of effort, which increases the expected utility of the financing enterprise and thus increases the value of the fund upon exit. However, due to the impact of information asymmetry, both parties choose conditions that are conducive to maximizing their own utility when making decisions, resulting in neither party's utility being at the optimal level.

Under the premise of maximizing the utility of financing enterprises, there is no incentive to enhance their own level of effort, and enterprises that cannot fully mobilize their enthusiasm can be regarded as low-quality projects. Under the condition of maximizing the utility of private equity investment funds, there is no incentive to increase the investment amount of the fund. So, in the real investment process, both parties choose conditions that are conducive to maximizing their own utility when making decisions. Private equity investment funds cannot

fully understand the true quality of financing enterprises, so they can only measure investment returns based on the average quality level of projects in the industry and provide corresponding investment quotas. Therefore, for high-quality projects, if the investment amount given by private equity investment funds is lower than the market average valuation level, companies will tend to give up introducing equity investors; On the contrary, for low-quality projects, if the investment amount given by private equity investment funds is higher than the average market valuation level, companies will actively introduce equity investors. This directly leads to the departure of high-quality projects from the market and the retention of low-quality projects, resulting in a decrease in the average quality of retained projects in the market and an increase in risk. Private equity investment funds will further lower the average valuation of projects in the market, resulting in a vicious cycle of fewer high-quality projects and a reversal of the private equity investment market.

4. Suggestions

As mentioned above, many factors are related to the Nash equilibrium of game among all players. In order to ensure the smooth development of private equity funds, it is necessary to design an effective incentive and punishment mechanism to ensure that all players perform positive behaviors.

Suggestion 1: Sign a phased investment agreement

The previous item $p \left[\frac{\partial(fgl)}{\partial I} R + fgl \frac{\partial R}{\partial I} \right] dI - (1 + \theta)dI = 0$ in equation 7 is the optimal decision condition for private equity investment funds regarding investment amount, and the last two items $pf(I)l(s) \left[g(e) \frac{\partial R}{\partial e} + g'(e)R \right] de$ and $pf(I)g(e) \left[l'(s)R + l(s) \frac{\partial R}{\partial s} \right] ds$ are both positive values. If the financing company improves its own level of effort, the expected returns of private equity investment funds upon exit will also increase. However, under the condition of maximizing the utility of private equity investment funds, there is no incentive to increase the investment amount of the fund. The investment amount I of private equity investment funds is positively correlated with the effort level e of financing enterprises. The larger the investment amount I , the higher the level of effort of the financing enterprise. In actual investment cases, financing companies with higher levels of effort also receive more investment amounts. When the investment amount I of the fund increases, it will also increase the effort level e of the incubator. The establishment of a game model theoretically explains how private equity investment funds and financing companies interact with each other.

The advantages of phased investment in the practice of private equity investment funds are obvious. By signing a phased investment agreement, private equity investment fund managers can periodically reassess the prospects and phased development status of the enterprise. Based on the reassessment results, if the subsequent development status of the financing enterprise is poor and the development prospects are bleak, the manager can suspend investment in the financing enterprise at a certain stage, Control the scale of losses caused by previous misjudgment decisions and terminate the original investment plan. If the development of the financing enterprise meets the expectations, the manager can continue the phased investment plan, share the expected revenue appreciation brought by the enterprise's development, and through phased communication and evaluation, can also enhance the transmission of information between the two parties and control the risks caused by information asymmetry.

On the contrary, from the perspective of financing enterprises, phased investment strategies also have advantages. If in the phased investment process, through the transmission of information, the financing enterprise has a further understanding of the financing strength, industry status, resource integration ability, and value-added service level of private equity investment funds. In the process of phased cooperation, evaluating whether the introduction of private equity investment funds has a good promoting effect on the development of the

enterprise can choose whether to continue cooperation at the end of the cyclical phase. You can continue to choose phased cooperation, or you can choose to introduce other investors. On the other hand, the batch injection of funds will also have an effective incentive and constraint effect on the project team of the financing enterprise. Staged injection can avoid excessive dilution of the equity of the financing enterprise itself, which is not conducive to fully mobilizing the enthusiasm of the enterprise's development, affecting the development momentum of the enterprise, and causing losses to the expected value upon exit. When the development of financing enterprises falls short of expectations, restrictive investment clauses are proposed, such as participating in investments at lower prices in subsequent stages, setting more selective clauses, and proposing stricter monitoring requirements. Notify these methods to mobilize the enthusiasm of financing enterprises.

Suggestion 2: Incentive mechanism and internal control

The previous item $(1-p)f(I)l(s)\left[g(e)\frac{\partial R}{\partial e} + g'(e)R\right]de - C'(e)de = 0$ in equation 6 is the condition for the optimal decision of the financing enterprise, with a maximum utility of 0, and the latter two items $(1-p)f(I)g(e)\left[l'(s)R + C(e)\frac{\partial R}{\partial e}\right]ds$ and $(1-p)\left[fgl\frac{\partial R}{\partial l} + \frac{\partial(fgl)}{\partial l}R\right]dl$ are both positive, indicating that an increase in the investment amount of the fund and an improvement in the level of value-added services will promote the expected value improvement of the financing enterprise. Increasing the investment amount and improving the level of value-added services provided by private equity investment funds will increase the expected value of financing enterprises. However, under the premise of maximizing the utility of financing enterprises, there is no incentive for financing enterprises to improve their own level of effort. The proportion of equity held by financing enterprises is $1-p$ positively correlated with their level of effort, the larger the proportion of shares held $1-p$, the higher the level of effort e .

Private equity investment funds cannot blindly increase the equity ratio of their financing companies in order to maximize their own utility. This will significantly weaken the enthusiasm of the financing enterprise itself, reduce the level of effort in the subsequent business development process, and affect the effectiveness of the entire project, resulting in a decrease in expected returns. Based on this theory, when a financing enterprise reaches a mature stage of operation, private equity investment funds can sell their stocks to the management of the financing enterprise, promote equity incentive mechanisms and employee stock ownership plans, further improve the level of effort of the financing enterprise, and promote the increase of residual equity value.

In the process of cooperation between private equity investment funds and financing enterprises, a sound internal control system is reflected in designing a series of agreements, improving and standardizing the financial audit system of the enterprise, optimizing the management structure of the enterprise, etc. This is conducive to reducing information asymmetry, standardizing enterprise management activities, and improving the level of value-added services for fund managers, promoting the development of enterprise operations. Promoting the improvement and improvement of the internal control system of enterprises is also the responsibility and obligation of the management of financing enterprises. Entrepreneurs are both management and equity owners, and the fund, as a vulnerable party to information asymmetry, is necessary to put forward requirements for a sound internal control system for financing enterprises.

Suggestion 3: Sign a gambling agreement

From the above analysis, it can be seen that under the condition of maximizing the utility of private equity investment funds, there is no incentive to increase the investment amount of the fund; Under the premise of maximizing the utility of financing enterprises, there is no incentive to enhance their own level of effort. Private equity investment funds and financing companies engage in speculative behavior before and after cooperation. Before cooperation, due to poor

business conditions, financing companies may be eager to cooperate with private equity investment funds in order to get out of difficulties. When information is asymmetric, this is a high-risk project for the fund. After cooperation, it can be concluded from the above analysis that the information asymmetry between private equity investment funds and financing enterprises can directly lead to speculative behavior and adverse selection problems.

The gambling agreement is not only an important means to avoid adverse selection issues, but also an effective way for both investment and financing parties to temporarily shelve valuation differences and share profit appreciation. Companies with the ability to match higher valuations often have high-quality projects, so gambling agreements can reflect the financing company's strong confidence in the good expectations and development of the project, and are willing to take risks. Signing gambling agreements for this not only indicates that the financing company is willing to accept the contract of "information screening" from fund investors, but also sends a signal of high-quality assurance. In addition, The gambling agreement also has a strong constraint and incentive effect on financing enterprises.

5. Conclusion

This paper discusses the coordination between the financing enterprises and private equity investment funds under the view of game theory. The aim of this article is to design a rational mechanism that can implement good risk control and capital appreciation through the design of a series of transaction structures. According to the analysis result mentioned above, we design a mechanism that can provide the effective cooperation between the financing enterprises and private equity investment funds. Based on China's national conditions and development status, We should adopt strategies such as phased investment, incentives and internal control, and signing gambling agreements from the perspective of transaction structure to effectively reduce the information uncertainty of private equity investment related entities, and reduce the possibility of market adverse selection and moral hazard occurrence.

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