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The incentive contract of diversification and angel investment: An analytical framework based on the principal-agent relationship

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ABSTRACT

Angel investments serve as an important source of venture capital for SMEs. This paper develops a model to study the impact of diversification to optimal contracts of angel investments via principal-agent theory based upon Holmstrom and Tirole's (1997) entrepreneur model. The model is then numerically simulated. Theory and numerical simulation suggest that when a set of angel investment projects are positively related, the degree of correlation among projects only affects the start-up firm's optimal payment and has no effect on the conditions for success of financing. The start-up firm's optimal payment increases with the degree of correlation among projects under certain conditions and decreases under other certain conditions.

1. Introduction

The financial term "angel" was created by the Insiders of Broadway and used to describe the wealthy private investors' risk investment for Broadway performance. During the 1980s, the venture research center of New Hampshire University in the U.S. defined "angel investment" as a private investment pattern from an academic perspective. Angel investment has become an indispensable part of the multi-level capital market in Europe and America and played an important role in promoting sustainable economic development. Barry (1994) pointed out that start-up firms in developing countries were financing themselves more from informal capital markets such as private groups or family members than on the imperfect formal venture capital market. Fiet (1995) found that venture capital companies often had diversified investment objectives that were diametrically to the views of the dangers of market and agency risk with angels. While venture capital companies are more concerned with market risk; the moral hazard induced by asymmetric information leads angels to be more concerned with agency risk. Therefore, angels focus more on selecting entrepreneurs than projects. Prowse (1998) studied the diversification of angels and found that active angels and passive angels are distintly different in project selection, incentive and control mechanisms, etc.

2. Overview

Gort (1962) was the earliest researcher to investigate the relationship between diversification and firm performance. His empirical results showed no significant relationship between diversification and firm performance. Rumelt (1982) subdivided diversification into related diversification and non-related diversification; his empirical research suggests that limited related diversification can improve a company's performance. Diamond (1984) proposed a theoretical model and proved that when investment projects are independent, diversification can increase incentive income but cannot reduce financing costs. However, Rajan *et al.* (2000) found that diversification may result in misallocation of capital, thereby reducing the company's income.

Chinese studies on diversity start from real-world experience and focus on examining the relationship between diversification and the value or performance of the company. Zhu Jiang's (1999) empirical research found that a company's diversification strategy had no significant effect on firm performance through. Zhang Weiguo *et al.* (2002) confirmed that the performance of a company that adopts a related diversification strategy is better than that of a firm which adopts a non-related diversification strategy. Lei *et al.* (2003) proposed that an industry with high concentration and high profitability should adopt a relevant diversification strategy. In contrast, an industry with low concentration and low profitability should adopt a non-related diversification strategy. Yan (2006) using a sample of diversified operating companies, established a positive empirical relationship between diversification strategy and firm performance.

Reviewing the history of China's capital market, the formal venture capital market began in 2009, but market size remains far lower than that required for economic and social development. Angel investment as an informal source of venture capital is widespread in many areas such as Jiangsu and Zhejiang provinces. Research on angel investment is still in the initial stage due to its confidential nature and privacy features. The few studies available focus more on the environment for the growth of angel investment and feasibility analysis in China.

The present paper is based on Holmstrom and Tirole's (1997) analytical framework, and uses principal-agent theory to study the optimal financing contract between the start-up firm and angels. We particularly emphasize the impact of diversification upon the optimal contract. The remainder of this paper is organized as follows. Section 3 makes a game model, between angels and start-up firm, and explains the economic meaning of the model. Section 4 solves the optimization model to find the optimal contract. Section 5 explores by numerical simulation the relationship between the optimal contract and the correlation of angel investment projects. Section 6 is the conclusion and outlook. The last section presents the limitations of the study and suggestions for further research.

3. Model

The angel investment market in China has undergone a certain degree of development, but is still in an embryonic stage. Many angel investors' idea still relies upon an earlier co-operative paradigm; that is to say, the investors are very interested in the projects but wish to cooperate only when project leaders also invest a certain amount of capital. In other words, most angel investors in China want to invest in start-up firms or teams that have already formed. Moreover, most angel investors only invest a small part of their funds initially, but then invest a lot morewhen the start-up firms have reached their intended targets. Typical examples include XuXin's investment in NetEase; the Wahaha group Cai Wensheng's in STORM software; Deng Feng's in the happy network; and Zhang Suyang's in Home Inns hotels. To reflect a combination of all of the above, we establish the following special model.

3.1 Basic Assumptions

There is asymmetric information between the start-up firm and angels, such that angels cannot observe the start-up firm's effort. For convenience, we make the following further assumptions:

H1: The start-up firm needs the risk investment in two related projects at the same time; each project requires a fixed investment I; the start-up firm's own assets equal $2A(0 < A < I)$ and they are in need of financing $2(I - A)$ from angels.

H2: The results of the two projects are displayed only after the start-up firm's hard work.

H3: Each project either "succeeds," that is yields verifiable income R; or "fails," that is yields no income.

H4: Behaving yields probability $p_H = 0.5$ of success and no private benefit to the start-up firm, and misbehaving yields probability $p_L = 0$ of success and private benefit B to the start-up firm.

H5: When the start-up firm is working, the probability that one project succeeds, conditional on the other project, is $(1+\alpha)/2$, where, $\alpha \in [-1,1]$.

H6: The start-up firm is local risk neutral with the following preferences:

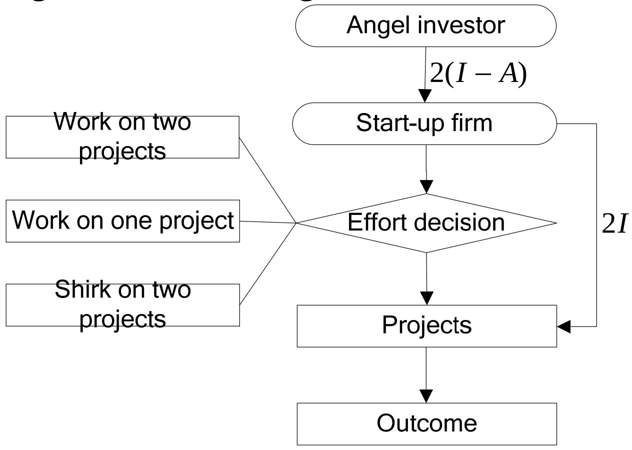
$$u(R_b) = \begin{cases} R_b & R_b \in [0, \overline{R}] \\ \overline{R} & R_b \geq \overline{R} \end{cases}$$

H7: Angels are risk neutral.

H8: Angels are perfectly competitive.

The game process between start-up firm and angels is shown in Figure 1.

Figure 1: Game timing



3.2 Payment Contract

Based on the game timing diagram and the basic assumptions above, we posit that the start-up firm and angels will take the following forms of financing contract:

Payment vector of angels: $(2R - R_2, R - R_1, -R_0)$

Payment vector of start-up firm: (R_2, R_1, R_0)

where R_2 denotes the start-up firm's payment when the number of successful projects is 2; R_1 the start-up firm's payment when the number of successful projects is 1; and R_0 the start-up firm's payment when the number of successful projects is 0. We further assume the start-up firm is limited liability, and therefore $R_2 \leq 2R$, $R_1 \leq R$.

3.3 Optimal Contract

Given the payment structure between angels and the start-up firm, the project investment has positive expected NPV if the start-up firm behaves, and negative NPV if it does not. Therefore, the design of the contract should be based upon the start-up firm's working on two projects.

Based on assumptions H4 and H5, it is easy to calculate the probability when the number of successful projects is 2, 1 and 0, respectively:

$$\frac{1+\alpha}{4},\ \frac{1-\alpha}{2},\ \frac{1+\alpha}{4}$$

Therefore, start-up firm's incentive constraints are:

- The expected return from working on both projects ≥ the expected return from shirking on both projects;
- The expected return from working on both projects ≥ the expected return return from shirking on one project.

A mathematical description can be given to these incentive constraints:

$$\frac{1+\alpha}{4}\mathrm{R}_2+\frac{1-\alpha}{2}\mathrm{R}_1+\frac{1+\alpha}{4}\mathrm{R}_0 \ge R_0+2B \qquad (1)$$

$$\frac{1+\alpha}{4}\mathrm{R}_2+\frac{1-\alpha}{2}\mathrm{R}_1+\frac{1+\alpha}{4}\mathrm{R}_0 \ge \frac{1}{2}R_1+\frac{1}{2}R_0+B \qquad (2)$$

To ensure financing costs, contract design ensure that the expected profit of angels be no less than the amount of its initial investment. The angels' participation constraint becomes:

$$\frac{1+\alpha}{4}(2\mathrm{R}-\mathrm{R}_2)+\frac{1-\alpha}{2}(\mathrm{R}-\mathrm{R}_1)+\frac{1+\alpha}{4}(0-\mathrm{R}_0)\ge 2(I-A)$$

Which reduces to

$$R-\left[\frac{1+\alpha}{4}\mathrm{R}_2+\frac{1-\alpha}{2}\mathrm{R}_1+\frac{1+\alpha}{4}\mathrm{R}_0\right]\ge 2(I-A) \qquad (3)$$

As the start-up firms are local risk neutral, the financing contract should not make the start-up firm's reward higher than $\overline{R}$ in any case, yielding the following boundary conditions:

$$R_2 \le \overline{R}\,,\ R_1 \le \overline{R}\ ,\ R_0 \le \overline{R} \qquad (4)$$

Considering all of the above incentive constraints, the participation constraint and the boundary conditions, the optimal contract is the solution of the following optimization problem:

$$\max_{\{R_2,R_1,R_0\}}\ \frac{1+\alpha}{4}\mathrm{R}_2+\frac{1-\alpha}{2}\mathrm{R}_1+\frac{1+\alpha}{4}\mathrm{R}_0$$

$$s.t\ \begin{cases}\frac{1+\alpha}{4}\mathrm{R}_2+\frac{1-\alpha}{2}\mathrm{R}_1+\frac{1+\alpha}{4}\mathrm{R}_0 \ge R_0+2B\\ \frac{1+\alpha}{4}\mathrm{R}_2+\frac{1-\alpha}{2}\mathrm{R}_1+\frac{1+\alpha}{4}\mathrm{R}_0 \ge \frac{1}{2}R_1+\frac{1}{2}R_0+B\\ R-[\frac{1+\alpha}{4}\mathrm{R}_2+\frac{1-\alpha}{2}\mathrm{R}_1+\frac{1+\alpha}{4}\mathrm{R}_0]\ge 2(I-A)\\ R_2\le\overline{R},\mathrm{R}_1\le\overline{R},R_0\le\overline{R}\end{cases}$$

where the objective function is the start-up firm's expected profit. The optimal contract should be that which maximizes the expected profit of the start-up firm on the basis of meeting the incentive constraints, participation constraint and boundary conditions.

4. Equilibrium and Its Properties

This section discusses the optimization problem to determine the optimal contract between the start-up firm and the angels. Setting the optimal contract and financing conditions for the success of the model depends upon exogenous parameter. The following discussion focuses on three cases.

Case one: $\overline{R}\ge[4R-8(I-A)]/(1+\alpha)$, that is $\overline{R}$ sufficiently large.[1]

Suppose (R_2^1,R_1^1,R_0^1) is the solution of the optimization problem above. There must exist $R_2^*\le\overline{R}$ such that:

$$R_2 = \frac{1+\alpha}{4}R_2^1+\frac{1\ \ \alpha}{2}R_1^1+\frac{1+\alpha}{4}R_0^1$$

It is straightforward to prove that $(R_2^*,0,0)$ satisfies the incentive constraints (1) and (2), as well as the participation constraint (3). Therefore, we only consider the optimal contract type as $(R_2,0,0)$. The optimization problem reduces to:

$$\max_{R_2}\ \frac{1+\alpha}{4}R_2$$

$$s.t\ \begin{cases}\frac{1+\alpha}{4}R_2\ge 2B\\ \frac{1+\alpha}{4}R_2\ge B\\ R-\frac{1+\alpha}{4}R_2\ge 2(I-A)\end{cases}$$

The solution of the optimization problem above is

$$R_2^*=\frac{4R-8(I-A)}{1+\alpha}$$

The optimal contract for start-up firm is:

$$(\frac{4R-8(I-A)}{1+\alpha},\ 0,\ 0)$$

where the necessary condition for the existence of an optimal solution is:

$$A\ge I+B-\frac{R}{2}$$

[1] This case corresponds to the start-up firms whose manager has strong ability and lofty ambitions.

but only when $R_2^* = [4R - 8(I-A)]/(1+\alpha) \le 2R$, that is $\alpha \ge 1 - 4(I-A)/R$. The optimal solution is reasonable. This conclusion suggests that only when the correlation between the two projects is high enough can the angels and start-up firm reach an incentive financing contract and venture capital projects to get financing.

The optimal contract shows that, when $\overline{R}$ is sufficiently large, that is to say the start-up firm is totally risk-neutral, its optimal payment decreases with the degree of correlation between projects and the amount of required external investment; and increases with the proceeds when the project is successful and self-funded. Besides the correlation between projects, the changing trend between the optimal payment of the start-up firm and the relative factors is the same under the single project. Only when the degree of correlation between projects surpasses a certain level could the projects obtain financing; the more the start-up firm has its own funds, the more it benefits when the project successful, and the more easily it will obtain financing. To the contrary, the more investment the project requires, the more the private benefits of the start-up firm, the more difficult it will be to obtain financing. When the degree of correlation between the projects is too small (or the negative correlation is too large), the incentive contract does not exist, and funding cannot be successful.

Thus, the start-up firms whose managers have superior ability should not select negatively-related projects; only managers do who lack superior ability will choose such projects in order to hedge their risks.

Case two:

$$\max\left\{\frac{8B-(1+\alpha)\overline{R}}{2(1-\alpha)}, \frac{(1+\alpha)\overline{R}-4B}{2\alpha}\right\} \le \overline{R} < \frac{4R-8(I-A)}{1+\alpha}$$

, that is $\overline{R}$ lies in the midrange and is more modest.[2]

The payment of the start-up firm should not exceed $\overline{R}$. We know from case one that there does not exist an optimal contract of type $(R_2, 0, 0)$, so we consider the optimal contract of type $(\overline{R}, R_1, R_0)$. The optimization problem reduces to:

$$\max_{\{R_2,R_1,R_0\}} \frac{1+\alpha}{4}\overline{R} + \frac{1-\alpha}{2}R_1 + \frac{1+\alpha}{4}R_0$$

$$s.t \begin{cases} \frac{1-\alpha}{2}R_1 - \frac{3-\alpha}{4}R_0 \ge 2B - \frac{1+\alpha}{4}\overline{R} \\ -\frac{\alpha}{2}R_1 - \frac{1-\alpha}{4}R_0 \ge B - \frac{1+\alpha}{4}\overline{R} \\ \frac{1-\alpha}{2}R_1 + \frac{1+\alpha}{4}R_0 \le R - 2(I-A) - \frac{1+\alpha}{4}\overline{R} \\ R_1 \le \overline{R}, R_0 \le \overline{R} \end{cases}$$

The solution of the optimization model differs because of α, yielding the following four cases of the optimal solution.

(i) When $\alpha < 0$, the solution of the optimization problem is:

$$R_1^* = \frac{4R - 8(I-A) - (1+\alpha)\overline{R}}{2(1-\alpha)}, \quad R_0^* = 0$$

where a necessary condition of the existence of optimal solution is:

$$B \le \min\left\{\frac{R}{2} - (I-A), \quad \frac{(1+\alpha)\overline{R} + 8\alpha(I-A) - 4\alpha R}{4(1-\alpha)}\right\}$$

(ii) When $0 \le \alpha \le 1/3$, the solution of the optimization problem is:

$$R_1^* = \min\left\{\frac{4R - 8(I-A) - (1+\alpha)\overline{R}}{2(1-\alpha)}, \frac{(1+\alpha)\overline{R} - 4B}{2\alpha}\right\},$$

$$R_0^* = 0$$

where a necessary condition of the existence of optimal solution is:

$$B \le \min\left\{\frac{R}{2} - (I-A), \ \frac{\overline{R}}{4}\right\}$$

[2] This corresponds to the start-up firms whose managers have some ability, but not strong enough, and are easily satisfied.

(iii) When $1/3 \le \alpha \le (\overline{R}-4B)/[4R-8(I-A)-\overline{R}-4B]$, the solution of the optimization problem is:

$$R_1^* = \frac{4R - 8(I-A) - (1+\alpha)\overline{R}}{2(1-\alpha)}, \; R_0^* = 0$$

where a necessary condition of the existence of optimal solution is:

$$B \le \frac{R}{2} - (I-A)$$

(iv) When $\alpha > (\overline{R}-4B)/[4R-8(I-A)-\overline{R}-4B]$, the solution of the optimization problem is:

$$R_1^* = \frac{(1+\alpha)\overline{R}-4B}{2\alpha} - \frac{(1-\alpha)[4R\alpha-8(I-A)\alpha-(1+\alpha)\overline{R}+4(1-\alpha)B]}{2\alpha(3\alpha-1)}$$

$$R_0^* = \frac{4R\alpha - 8(I-A)\alpha - (1+\alpha)\overline{R} + 4(1-\alpha)B}{3\alpha - 1}$$

where a necessary condition of existence of optimal solution is:

$$B \le I - A - \frac{R-\overline{R}}{2}$$

In case (iv), the payment of the start-up firm is non-zero even there are no successful projects. Since ths is obviously unreasonable, such a contract should be excluded. We therefore analyze only the first three cases.

Firstly, when $\overline{R}$ is more modest, the optimal payment of the start-up firm in the case that two projects are successful R_2^* always equals $\overline{R}$. The optimal incentive contract is primarily revealed by the payment of the start-up firm in the case that only one project is successful. In this case, the relationship between the optimal payment of start-up firm R_1^* and the degree of correlation between projects α depends upon the value of other parameters. In fact, when $\overline{R} > 2R - 4(I-A)$, the optimal payment of the start-up firm increases with the degree of correlation between projects; when $\overline{R} < 2R - 4(I-A)$, the optimal payment of start-up firm decrease with the degree of correlation between projects . However, when the degree of correlation between projects is too high, the incentive contract is unreasonable.

Secondly, when $\overline{R}$ is more moderate, the optimal payment of the start-up firm R_1^* increases with the benefit when the project is successful R and the start-up relies upon its own funds; but decreases with the external investment required $I-A$ and $\overline{R}$.

Lastly, when $\overline{R}$ is more moderate and the two projects are positively correlated, the condition of successfully financing the projects is independent of the correlation. The larger R and A, the easier project financing; and the larger $I-A$ and B the more difficult. When the projects are negatively correlated, the correlation between projects affects not only the optimal payment of the start-up firm, but also project financing.

We conclude that the angels should give toe start-up firms whose managers are easy to satisfy a fixed payment equal to their highest utility when the number of successful projects is 2; but an optimal payment related to other factors when the number of successful projects is 1.

Case three: $\overline{R} < \max\{[8B-(1+\alpha)\overline{R}]/[2(1-\alpha)], [(1+\alpha)\overline{R}-4B]/(2\alpha)\}$, that is $\overline{R}$ is very small.

In this case there only exists the optimal contract type as $(\overline{R}, \overline{R}, R_0)$, where, $R_0 \ne 0$. We cannot imagine the start-up firm getting non-zero payment when both projects fail without considering the residual value of assets in the model, so we do not analyze the contract in this case.

5. Numerical Simulation

In this section we focus on the relationship between the optimal payment of the start-up firm and the degree of correlation between projects. In the following simulations, we set the parameters to:

$$I = 5500, \; A = 1000, \; R = 12000, \; B = 1000$$

Case one: When $\overline{R} \ge 12000/(1+\alpha)$, that is $\overline{R}$ is sufficiently large.

According to the theoretical analysis, if and only if both projects are successful can the start-up firm receive a positive payment. Here we only give the figure about the relationship between the optimal payment of start-up firm R_2^* and the degree of correlation α. Figure 2 corresponds to the situation where correlation is less than -0.5, and Figure 3 greater than -0.5.

Figure 2: The relationship between R_2^* and α

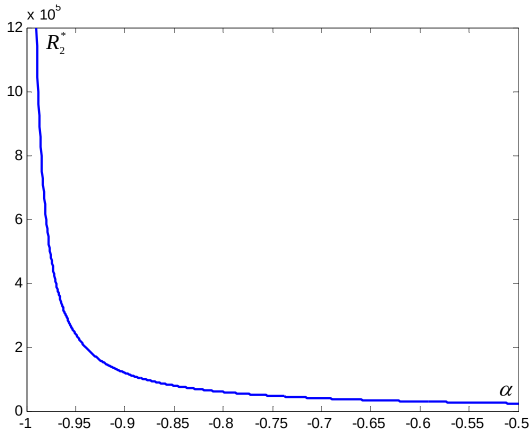
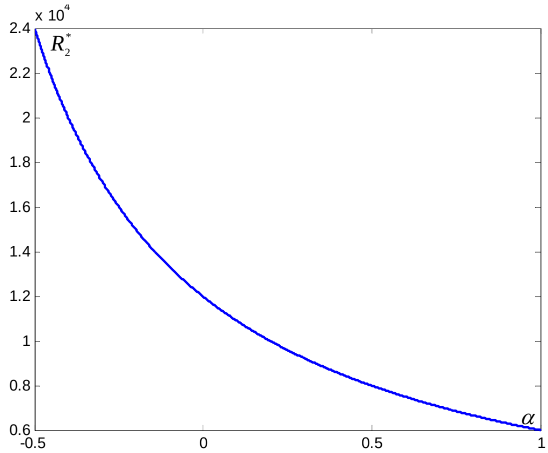


Figure 3: The relationship between R_2^* and α



Figures 2 and 3 show that the optimal payment of the start-up firm decreases with the degree of positive correlation between projects when both are successful, but increases with the degree of negative correlation between projects. This is because the probability that both projects will be successful increases with the degree of their positive correlation. This implies that the payment of the start-up firm when both the two projects are successful should decrease under the condition that the expected payment is unchanged, and decreases with the degree of negative correlation between the two projects. The payment of the start-up firm when both the two projects succeed should increase under the condition that the expected payment unchanged. Moreover, when the negative correlation between the two projects is greater than 0.5 (that is the correlation is less than -0.5), the benefit to the start-up firm when two projects are successful is more than the total receipts when both the two projects succeed, which is obviously impossible. Therefore, when the degree of negative correlation between the two projects is too high, an incentive compensation contract giving the start-up firm payment only when both the two projects are successful does not exist. In fact, few start-up firms will choose two projects with too high a degree of negative correlation.

Case two: when $\max\left\{\frac{8000-(1+\alpha)\bar{R}}{2(1-\alpha)}, \frac{(1+\alpha)\bar{R}-4000}{2\alpha}\right\} \le \bar{R} < \frac{12000}{1+\alpha}$, that is $\bar{R}$ is more modest, and $\alpha < (\bar{R}-4000)/[8000-\bar{R}]$

As $R_2^* = \bar{R}$, here we only give the Figure of the relationship between the optimal payment to the start-up firm R_1^* and the degree of correlation α. Figure 4 shows the relationship between R_1^* and α when $6000 < \bar{R} < 12000/(1+\alpha)$, Figure 5 when $\bar{R} < 6000$.

Figure 4: The relationship between R_1^* and α

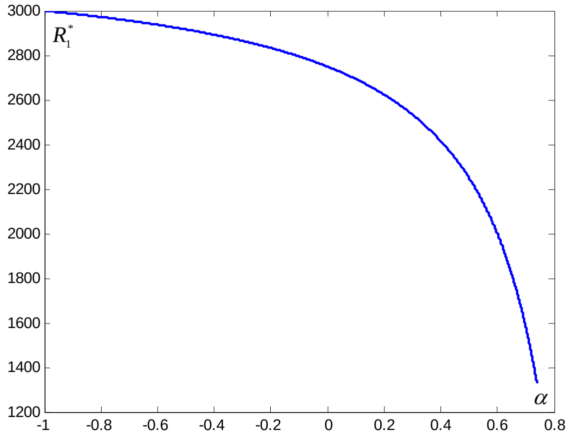


Figure 5: The relationship between R_1^* and α

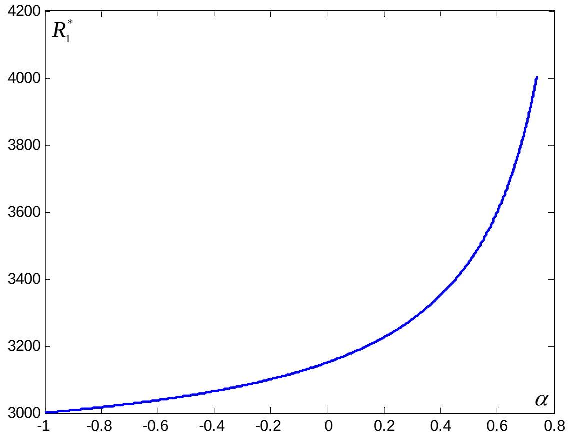


Figure 4 shows that the optimal payment to start-up firm R_1^* decreases with the degree of correlation between the projects α under the specific condition that $6000 < \overline{R} < 12000/(1+\alpha)$; Figure 5 shows that the optimal benefit of start-up firm R_1^* increases with the degree of correlation between the projects α only when $\overline{R} < 6000$.

6. Conclusion

This study is based on Holmstrom and Tirole's (1997) analytical framework, and uses the principal-agent relationship to study the optimal financing contract between the start-up firm and angels. It particularly emphasizes the impact of diversification on the optimal contract and the conditions for successful financing under the assumption of local risk-neutrality of the start-up firm. Theory and numerical simulation show that:

(1) The optimal contract is affected not only by the proceeds when the projects succeed, the start-up firm's own funds, the investment required, private benefit and other factors; but also by the start-up firm's local risk-neutrality . We will get different optimal contracts when the risk-neutrality of start-up firms differs. Especially, when the start-up firm is completely risk averse, the optimal incentive contract does not exist.

(2) A positive relation affects only the optimal contract, not the financing results. A negative relation affects not only the optimal contract of angel investment but also the condition of financing; If the degree of negative correlation between projects is too high, the projects are not funded.

(3) When the start-up firm is fully risk neutral, the changing trend between the optimal payment to the start-up firm and the likelihood of successful financing changes with the proceeds, the start-up firm's own funds, the investment required by the project, private benefit and other factors are the same in the case of single project. The changing trend is unrelated to the correlation, which only affects the optimal payment.

(4) When the start-up firm is locally risk neutral, the optimal payment increases with the degree of correlation between projects under certain conditions, and decreases under certain other conditions.

This study has important policy implications. With the continuous development of our economy and the deepening of economic reform, the environment for the development of angel investment has formed. The healthy development of angel investment can improve China's capital market and promote the effective allocation of social resources as a supplement to the formal venture capital market, thereby easing the financing problems of SMEs. Therefore, China should learn from the advanced experience of foreign countries how best to combine capital markets, laws and regulations, social cultural and other related environmental factors to develop policies to promote the healthy development of angel investment.

7. Suggestions for Further Research

This study has been simplified in many aspects. For example, we only consider two related projects carried on at the same time rather than sequentially; the start-up firm has bargaining power but angels can only accept the "ultimatum" type of contract; angels are risk neutral; and so on. These assumptions can be fully extended within the framework of this paper, and are more amply explored in the authors' other papers.

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