JUSTC Article
http://justc.ustc.edu.cn
Received: January 04, 2022; Accepted: March 26, 2022

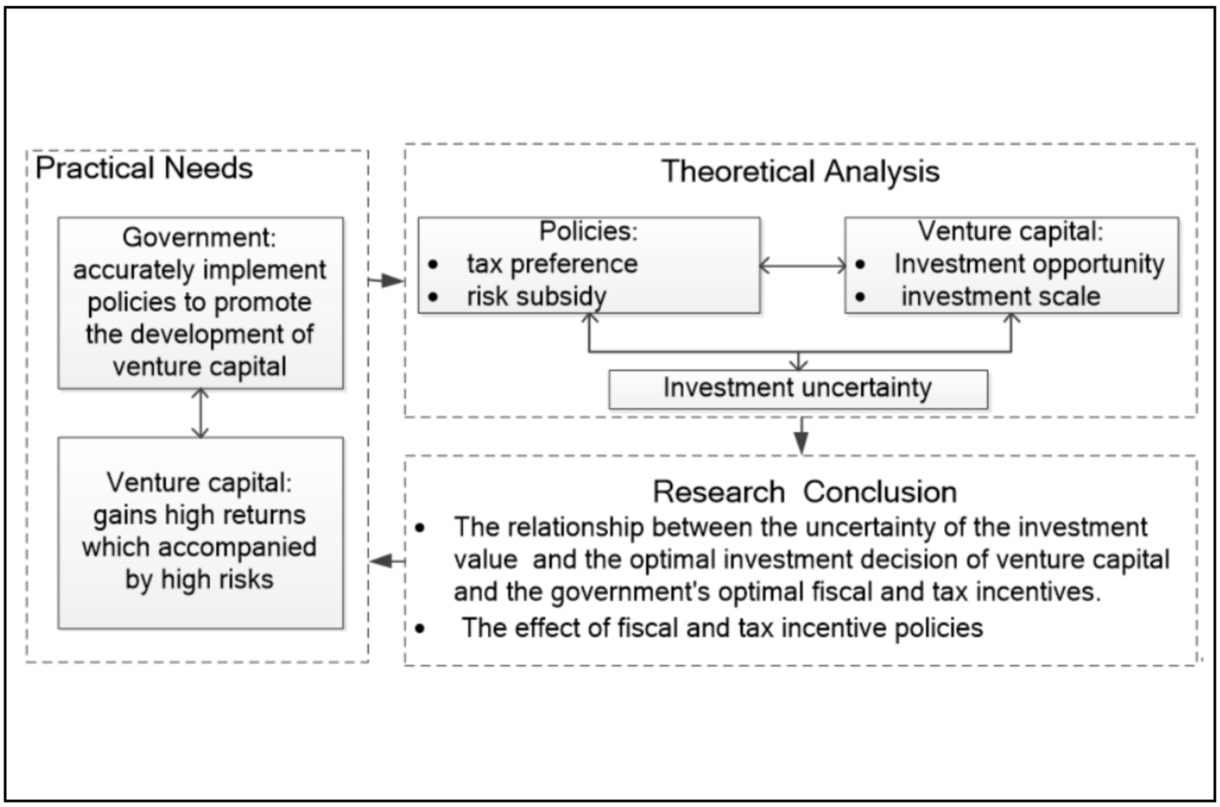
The optimization and selection of venture capital incentive policies under uncertain condition

Wenjun Yan[1], Jiaqi Zhang[1], Jianing Xu[1], Haonan He[1] ✉, and Shanyong Wang[2]

[1]*School of Economics & Management, Chang'an University, Xi'an 710054, China;*
[2]*School of Public Affairs, University of Science and Technology of China, Hefei 230026, China*

✉Correspondence: Haonan He, E-mail: haonanhe@chd.edu.cn

Graphical abstract



The optimal decision is obtained for venture capitals to invest startups and for governments to provide investment incentives based on the option game model.

Public summary

■ This work constructs an option game model of government and venture capital institutions based on both tax incentives and risk subsidies.

■ The impact of uncertainty on optimal risk investment decisions and policies is measured.

■ The differences in the roles of the two investment incentive policies in different uncertainty intervals are obtained, which provides theoretical support for investment decision-making and incentive policy formulation.

Citation: Yan W J, Zhang J Q, Xu J N, et al. The optimization and selection of venture capital incentive policies under uncertain condition. *JUSTC*, **2022**, 52(8): 8. DOI: 10.52396/JUSTC-2022-0011

JUSTC Article
http://justc.ustc.edu.cn Received: January 04, 2022; Accepted: March 26, 2022

The optimization and selection of venture capital incentive policies under uncertain condition

Wenjun Yan[1], Jiaqi Zhang[1], Jianing Xu[1], Haonan He[1] ✉, and Shanyong Wang[2]

[1]School of Economics & Management, Chang'an University, Xi'an 710054, China;
[2]School of Public Affairs, University of Science and Technology of China, Hefei 230026, China

✉Correspondence: Haonan He, E-mail: haonanhe@chd.edu.cn

Cite This: *JUSTC*, **2022**, 52(8): 8 (10pp) Read Online

Abstract: Venture capital is crucial innovation capital. A venture capital option game model is constructed to obtain an incentive strategy that drives venture capital to actively allocate resources to support innovation based on risk subsidies and tax incentives. Moreover, the implementation effect of venture capital incentive policies under the value-uncertain condition of the entrepreneurial enterprise is studied. The results illustrate that when the uncertainty of the value of the entrepreneurial enterprise is less than the threshold, the tax preference policy is more effective in accelerating the investment decision-making of venture capital institutions. In contrast, the two policies have identical effects. When the uncertainty of the value of the entrepreneurial enterprise is less than the threshold, the risk subsidy policy has a better effect on increasing the investment scale of venture capital institutions, while the two policies have the same effect.

Keywords: option game; venture capital; risk subsidy; tax preference; uncertainty

CLC number: F812.4 **Document code:** A

1 Introduction

Venture capital converges innovative elements through market forces and is an essential channel for developing early-stage entrepreneurial enterprise equity financing. To drive venture capital to focus on early-stage entrepreneurial enterprises and alleviate the inefficient allocation of innovative resources caused by uncertain risks, a series of policies have been issued to provide venture capital institutions with direct risk subsidies or indirect tax preferences[1] to internalizing their externalities[2]. Although certain results have been achieved, the effect has not reached expectations. Venture capital investment in our country is insufficient for seed and start-up ventures[3, 4], whereas the development of innovative enterprises in the seed and start-up stages is a new, sustainable driving forces for the country's innovation and development. Therefore, it is urgent to reveal the mechanism by that the value uncertainty risk of entrepreneurial enterprises affects the decision-making of venture capital institutions after the implementation of incentive policies for venture capital and to provide optimization and selection strategies for incentive policies based on this.

Investors' investment decision-making is deeply influenced by the uncertainty of entrepreneurial enterprise value and investment incentive policies[5] , which has been confirmed by the academic circles and the industry. Huang et al.[6] indicated that the flow of project funds is usually uncertain, and it is difficult for investors to accurately estimate the value of the project, which creates obstacles to investment decision-making. Wang and Qian[7] showed that many non-probabilistic factors affect the financial market, and the rate of return on risky assets is vague and uncertain. Dai et al.[8] stated that the choice of investment depends on multiple interrelated variables and that the feasibility of the project is affected by risk factors. Wang and Qie[9] revealed that price volatility, the government subsidy coefficient, and the proportion of income transfer between enterprises in the supply chain all have an impact on the investment threshold.

The current has not reached a conclusion. Some scholars believe that incentive policies boost investment institutions for technological innovation[10, 11]. Sendstad and Chronopoulos[12] stated that a shrinking subsidy reduces investment motivation. Huang et al.[6] pointed out that a tax exemption policy can help directly lower the investment threshold, and lower unit operating costs and significantly expand the optimal investment scale. Zhou and Pan[13] stated that financial subsidies would soar transaction costs in two major ways, whereas the increase in transaction costs due to tax reductions and exemptions are relatively small. Agénor, Neanidis[14] and Lin, Luan[15] found that public capital or government subsidies have a significant positive impact on innovation. Chen et al.[16] found that government subsidies are an effective way to promote innovation and the effectiveness of subsidies is mainly reflected in their scale. However, some studies show that financial subsidies and tax incentives negatively affect investment institutes for technological innovation. Alperovych et al.[17] stated that private venture capital is more efficient than government venture capital. Jung and Feng[18] investigated the government's subsidy design problem for firms' green technology development in an evolving industry. If the government only considers the environmental benefits of techno-

DOI: 10.52396/JUSTC-2022-0011
JUSTC, **2022**, 52(8): 8

logy and its costs, the subsidy policy may be detrimental to the environment. Redonda et al.[19] found that tax incentives are costly, often ineffective, and cause side effects.

In terms of optimization of investment incentive policies, Zhao and Chen[20] established an optimal subsidy principal-agent model to discuss the optimal subsidy level from the perspective of maximizing the net benefits of the policy, that improving investor preferences and eliminating information asymmetry will help reduce subsidy costs. Zhao and Guan[21] built a dynamic simulation model of technological innovation based on social science computing experimental methods, and explored the impact of different policy tools and their combinations on corporate environmental technology innovation behavior by simulating the process of corporate environmental technology innovation under different environmental policy scenarios. Xu and Meng[22] based on mandatory emission reduction, economic performance, and environmental performance have been taken into account to build an evolutionary game model.

The existing literature has laid the theoretical foundation for this study. Simultaneously, two points are noteworthy. First, in the study of incentive policy optimization, the decision-making behavior of the motivated party[23, 24, 25] and risk control[26] are fully considered. Second, among many incentive policies that encourage innovation, tax incentives and risk subsidies have always been the two most common and effective innovation policies used by governments in various countries. Tax breaks reduce government income, and risk subsidies increase government expenditure. These two policies are significantly different for governments, and it is necessary to conduct a comparative analysis of these two policies. However, there is a lack of in-depth discussion on the effect of the implementation of incentive policies to promote venture capital, especially the difference in the role of tax incentives and risk subsidies for venture capital, and which has fundamental theoretical and practical significance for the precise implementation of policies to stimulate the vitality of innovative capital. Based on the above analysis, this study focuses on how the uncertainty of the value of entrepreneurial enterprise affects the investment behavior of venture capital institutions and the optimal choice of government incentive behavior, and from the perspective of the investment timing and scale of venture capital institutions, discusses the different effects between risk subsidies and tax incentives.

2 Construction of optimal decision model of venture capital and government incentive based on option game

Since the government formulates investment incentive policies to promote venture capital to support innovative and entrepreneurial enterprises. In this activity, venture capital institutions face uncertain investment risks, and policies must be precise and effective. Meanwhile, suppose the game relationship between venture capital and policymakers is not considered. In that case venture capital decisions do not consider the reduced investment costs due to incentive policies and may miss the investment opportunities, and the intensity of government investment is relatively arbitrary, which reduces the efficiency of resource allocation. The option game theory can only be applied to solve decision uncertainty and participant game problems. Therefore, we analyzes venture capital decisions and policy incentives.

This section discusses the equilibrium state of the game between venture capital institutions and the government under the two major incentive policies of risk subsidies and tax incentives for venture capital institutions and obtains the analytical solution of the optimal decision-making between venture capital institutions and the government when the game reaches the equilibrium state. It lays the foundation for the relationship between the uncertainty of entrepreneurial enterprise value, the optimal investment decisions of venture capital, and the optimal investment incentive policies in the following sections.

2.1 Basic assumptions

To study the optimal investment decisions of venture capital institutions and investment incentive policies, it is necessary to clarify the options game process between venture capital institutions and the government. The following basic assumptions were made:

The venture capital institutions and the government are in line with the rational person's assumption. The optimal investment decisions and optimal risk subsidies and tax incentives are the results of the non-cooperative game between venture capital institutions and the government, which take the principle of maximizing their objective functions to make decisions independently in turn. Among them, this study examines incentive methods for compensating the risk of venture capital institutions in the risk subsidy policy and the incentive methods for deducting the taxable income of venture capital institutions in the preferential tax policy.

Taxation is the economic foundation of government machinery, and is the economic manifestation of a country's existence[27]; therefore, it is assumed that taxation is an integral part of the government's objective function.

Venture capital institutions only make equity investments. Assuming that the equity investment of venture capital institutions accounts for the proportion of equity investment in the entire project as ρ, then the equity value of venture capital institutions is ρ times the equity value of the entire project, in which $\rho \in (0,1)$.

Assuming that time is continuous, $t \in (0,+\infty)$, both venture capital institutions and the government can only observe the uncertain capital flow of entrepreneurial enterprises and make decisions accordingly. Capital flow x obeys geometric Brownian motion[28], where $\mathrm{d}x_t = \mu x_t \mathrm{d}t + \sigma x_t \mathrm{d}W_t$, $x_0 > 0$, $\mathrm{d}W_t$ is the Wiener process increment, μ is the drift rate, and σ is the volatility rate, σ^2 represents the uncertainty in the value of the entrepreneurial enterprise.

When the venture capital institution invests I in the entrepreneurial enterprise selected, it obtains the capital flow $(1-\tau)x_t\pi(I)$, where $\tau \in (0,1)$ is the income tax rate of the venture capital institution. Assuming that the projects invested by venture capital institutions have a scale, according to existing research, if the scale is too large, it is likely to enter the returns-to-scale diminishing stage. $\pi(I)$ reflects the law of returns-to-scale diminishing and $\pi(I) = \dfrac{I}{I+1}$[28]. Then, the project value is

$$V(x_t,I)=E^{x_t}\left[\int_t^{\infty}(1-\tau)x_z\pi(I)\mathrm{e}^{-r(z-t)}\mathrm{d}z\right]=(1-\tau)\pi(I)\frac{x_t}{r-\mu}, \tag{1}$$

where $r\in R_+$ is the risk-free rate of return and $r>\mu$. The venture capital institution chooses to invest when it observed that the project capital flow x reaches the investment threshold x_j for the first time, and the investment timing of the venture capital institution is

$$t_j=\inf\{t>0\mid V_t\geqslant V(x_j,I_j)\}. \tag{2}$$

According to the development law of entrepreneurial enterprises, the lower the investment threshold, the earlier the investment timing. To simplify the mathematical expression, the following analysis is based on investment threshold x_j instead of investment timing t_j.

2.2 Construction of decision models for venture capital and government incentives

The game process between venture capital institutions and the government is illustrated in Fig. 1. At time 0, the government first gives a signal of incentive decisions; venture capital institutions act accordingly and make investment decisions at time 1 based on the government's decision signal at time 0, after which the government observes the effect of the incentives. The adjusted optimal investment incentive policy will be given at time 2 according to the investment decision of the venture capital institution made; the venture capital institution then adjusts according to the government's policy at time 2 and will obtain the optimal investment decision under the equilibrium state at time 3. After rounds of adjustments from 0 to 3, the optimal investment decision of venture capital institutions and the government's optimal investment incentive policies will only be related to the entrepreneurial enterprise selected itself, and will no longer be affected by the decision of the other party.

Based on the above analysis, the following section constructs optimal decision-making models for venture capital and its incentive policies from the perspective of risk subsidies (Scenario 1) and taxation (Scenario 2).

2.2.1 Scenario 1: Decision-making model for venture capital and its government risk subsidy incentives

Implementing risk subsidy for venture capital is a commonly used incentive policy. In order to obtain the optimal decision for venture capital institutions and government under the game, this study takes the risk subsidy policy for venture capital institutions as a representative, and based on the option game theory, we construct a decision-making model for venture capital and its government risk subsidy incentives, analyze the optimal investment decision of venture capital institutions for enterprises selected under uncertain conditions and the government's optimal subsidy policy for venture capital institutions.

Venture capital institution objective function: It is composed of the difference between its equity value return and investment cost. The equity value return is ρ times the equity value of the entire project. The venture capital institution conducts equity investment for the venture enterprise, and the level of funding provided is I_s, and the government's risk subsidy s directly reduces the investment cost of venture capital institutions. Its investment cost is (I_s-s). The objective function of venture capital institutions is

$$F(x_0,s)=\sup_{x_s\geq x_0,I_s\geq 0}E^{x_0}\left[\mathrm{e}^{-rt_s}(\rho V_s(x_s,I_s)-(I_s-s))\right]. \tag{3}$$

The project value is assumed to be $V_s(x_s,I_s)=(1-\tau)\cdot\pi(I)\frac{x_s}{r-\mu}$. According to the research of Lukas and Thiergart[28], the following equation holds

$$E^{x_0}(\mathrm{e}^{-rt_s})=\left(\frac{x_0}{x_s}\right)^{\beta_1}, \tag{4}$$

where $\beta_1=f(\sigma^2)=0.5-\frac{\mu}{\sigma^2}+\sqrt{\left(\frac{\mu}{\sigma^2}-0.5\right)^2+\frac{2r}{\sigma^2}}>1$[13–14]. Substituting it into the objective function of venture capital institutions, and sorting out the equations, then,

$$F(x_0,s)=\sup_{x_s\geq x_0,I_s\geq 0}\left(\frac{x_0}{x_s}\right)^{\beta_1}\left(\rho(1-\tau)\pi(I)\frac{x_s}{r-\mu}-I_s+s\right). \tag{5}$$

Government objective function: The government's objective function is composed of the difference between the tax brought by the value of the entrepreneurial enterprise and the risk subsidy provided for the venture capital institution. The projected tax is paid together by the venture enterprise and the venture capital institution. The government's objective function is

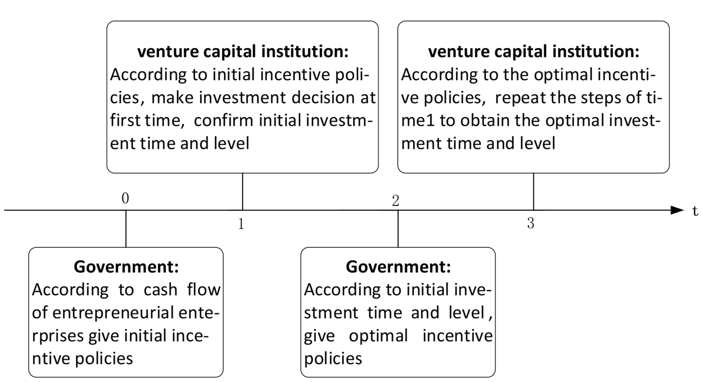


Fig. 1. Game flow chart between venture capital institutions and government options.

DOI: 10.52396/JUSTC-2022-0011
JUSTC, **2022**, 52(8): 8

$$G(x_0)=\sup_{s>0}\left(\frac{\tau}{r-\mu}\pi I_s x_s - s\right)\left(\frac{x_0}{x_s}\right)^{\beta_1}. \tag{6}$$

2.2.2 Scenario 2: Decision-making model for venture capital and its government tax preference

Among the many factors that influence investment decisions, taxation is an important factor for investors to consider.

At T, the moment of tax payment, the capital flow of innovation projects is constant x_T, the taxable income of the entire project is $\pi(I)\frac{x_T}{r-\mu}$, and the taxable income of venture capital institutions is $\rho\pi(I)\frac{x_T}{r-\mu}$. In terms of tax incentives, the taxable income of venture capital institutions deduced by ratio is $v=\epsilon\rho\pi(I)\frac{x_T}{r-\mu}$, where $\epsilon\in(0,1)$ is the deduction ratio. Compared to no tax incentives, the amount of tax paid by venture capital institutions is τv.

The objective function of venture capital institutions: It is composed of the difference between its equity value income and the investment cost. And its equity value income is ρ times the equity value of the entire project. The venture capital institution invests in equity investment in the entrepreneurial enterprise, and the level of funds provided by the venture capital institution is I_v, if the taxable income v is deducted proportionally, then the less amount of tax paid is τv, which directly reduces the investment cost of the venture capital institution, then its investment cost is $(I_v-\tau v)$. The objective function of the venture capital institutions is

$$F(x_0,v)=\sup_{x_v\geq x_0, I_v\geq 0} E^{x_0}\left[\mathrm{e}^{-rt_v}\left(\rho V_v(x_v,I_v)-I_v+\tau v\right)\right].$$

The project value is assumed to be $V_v(x_v,I_v)=(1-\tau)\pi(I)\frac{x_v}{r-\mu}$, then,

$$F(x_0,v)=\sup_{x_v\geq x_0, I_v\geq 0}\left(\frac{x_0}{x_v}\right)^{\beta_1}\left(\rho(1-\tau)\pi(I)\frac{x_v}{r-\mu}-I_v+\tau v\right). \tag{7}$$

The government's objective function: It is composed of the difference between the tax brought by the project value and the tax incentives that make venture capital institutions pay less tax. The government's objective function is

$$G(x_0)=\sup_{v>0}\left(\frac{\tau}{r-\mu}\pi I_v x_v-\tau v\right)\left(\frac{x_0}{x_v}\right)^{\beta_1}. \tag{8}$$

2.3 Optimal decision analysis of venture capital and government incentives

According to the analysis of venture capital and its government's risk subsidy incentive decision-making model and venture capital and its government's tax incentive decision-making model, to obtain the optimal decision on the venture capital institution investment and its government's incentives in the equilibrium state, based on the risk subsidy and tax policy respectively. The conclusions are presented in Theorems 2.1 and 2.2, respectively.

Theorem 2.1. According to Scenario 1, under the risk subsidy policy, the optimal investment threshold and investment scale of venture capital institutions in the equilibrium state are

$$\hat{x}_s^*=\begin{cases}\frac{r-\mu}{\rho(1-\tau)}\left(\frac{(2\beta_1-1)2\xi-\psi+\sqrt{[\psi^2+4\xi(1-\tau)\beta]}}{4(\beta_1-1)\xi}\right)^2, & \tau>\frac{1}{\beta_1+1};\\ \frac{r-\mu}{\rho(1-\tau)}\left(\frac{\beta_1}{\beta_1-1}\right)^2, & \text{else};\end{cases} \tag{9}$$

$$\hat{I}_s^*=\begin{cases}\frac{2\xi-\psi+\sqrt{\psi^2+4\xi\beta_1(1-\tau)}}{4\xi(\beta_1-1)}, & x_s>x_0,\ \tau>\frac{1}{\beta_1+1};\\ \frac{1}{\beta_1-1}, & x_s>x_0,\ \tau\leqslant\frac{1}{\beta_1+1};\\ \sqrt{\rho\frac{1-\tau}{r-\mu}x_0}-1, & x_s\leqslant x_0.\end{cases} \tag{10}$$

where $\xi=\beta_1+\tau-1$, $\psi=(\tau(1+\beta_1)-1)(2\beta_1-1)$.

Proof. In the analysis of the game process between venture capital institutions and the government, we assume that the risk subsidy provided by the government is s, construct the objective function of venture capital institutions, and use the optimization method to maximize the objective function to solve the optimal investment decision of venture capital institutions at this time. Solving the first-order partial derivatives of venture capital institutions' objective functions forx_s and I_s, the first-order conditions for maximizing them can be obtained as follows,

$$\begin{cases}\frac{\rho(1-\tau)}{r-\mu}\frac{1}{(I_s+1)^2}x_s=1,\\ \frac{\rho(1-\tau)}{r-\mu}\frac{I_s}{I_s+1}x_s=\frac{\beta_1}{\beta_1-1}(I_s-s).\end{cases}$$

Solving this equation system, the investment threshold $\hat{x}_{1s}$ and investment scale $\hat{I}_{1s}$ of venture capital institutions at time 1 are obtained:

$$\hat{x}_{1s}=\begin{cases}\max(x_0,A), & 4\beta_1(\beta_1-1)s\leqslant 1;\\ x_0, & \text{else};\end{cases}$$

$$\hat{I}_{1s}=\begin{cases}\frac{1+\sqrt{1-4\beta(\beta_1-1)s}}{2(\beta_1-1)}, & x_s>x_0;\\ \sqrt{\rho\frac{1-\tau}{r-\mu}x_0}-1, & x_s\leqslant x_0;\end{cases}$$

where for the simplified result, let $A=\frac{r-\mu}{\rho(1-\tau)}\left(\frac{2\beta_1-1+\sqrt{1-4\beta_1(\beta_1-1)s}}{2(\beta_1-1)}\right)^2$. The government's goal is to maximize its objective function. Given the investment timing and investment scale of venture capital institutions, solving the first-order optimal conditions of the function can obtain the government's optimal risk subsidy amount at time 2. The first-order derivative of the government objective function to s and the first-order condition for maximizing the government objective function is $\frac{2\beta_1 s}{(I+1)(2(\beta_1-1)I-1)}=\frac{\tau}{1-\tau}-\frac{1}{\beta_1}$.

DOI: 10.52396/JUSTC-2022-0011
JUSTC, **2022**, 52(8): 8

The second-order condition is $\tau > \frac{1}{\beta_1 - 1}$. By classifying and discussing the relationship between capital flow x_0 and the investment threshold x_s and solving the equation, the optimal government risk subsidy level s^* at time 2 is obtained as,

$$s^* = \begin{cases} 0, & \left(\frac{\beta_1}{\beta_1 - 1}\right)^2 < \frac{\rho(1-\tau)}{r-\mu}x_0; \\ \min\{S_{s1}, S_{s2}\}, & \left(\frac{2\beta_1 - 1}{2(\beta_1 - 1)}\right)^2 < \frac{\rho(1-\tau)}{r-\mu}x_0 < \left(\frac{\beta_1}{\beta_1 - 1}\right)^2; \\ S_{s2}, & \text{else;} \end{cases}$$

where,

$$S_{s1} = \frac{1 - \left(2(\beta_1 - 1)\sqrt{\frac{(1-\tau)\rho}{r-\mu}x_0} - 2\beta_1 + 1\right)^2}{4\beta_1(\beta_1 - 1)},$$

$$S_{s2} = \begin{cases} \frac{2\xi^2 - \psi^2 - 2\xi(1-\tau)\beta_1 \pm \psi\sqrt{[\psi^2 + 4\xi(1-\tau)\beta_1]}}{8\beta_1(\beta_1 - 1)\xi^2}, & \tau > \frac{1}{\beta_1 + 1}; \\ 0, & \text{else;} \end{cases}$$

where for the simplified result, let $\xi = \beta_1 + \tau - 1$, $\psi = (\tau(1+\beta_1) - 1)(2\beta_1 - 1)$.

Substituting the optimal risk subsidy s^* into the investment scale $\hat{I}_{1s}$ and investment threshold $\hat{x}_{1s}$ of the venture capital institution, the optimal investment threshold $\hat{I}_s^*$ and investment scale $\hat{x}_s^*$ of the venture capital institution can be obtained in the equilibrium state, that is, the proof is obtained.

Theorem 2.2. According to Scenario 2, under the preferential tax policy, the optimal investment threshold and the investment scale of venture capital institutions in the equilibrium state are:

$$\hat{x}_v^* = \begin{cases} \frac{r-\mu}{\rho(1-\tau)}\left(\frac{(2\beta_1 - 1)2\phi_v + \sqrt{4\phi_v^2 - 4\tau\xi_v\phi_v + 2\psi_v{}^2\tau^3 - 2\psi_v\tau\sqrt{[\psi_v{}^2\tau^4 - 4\xi_v\phi_v\tau^2 + 4\phi_v^2]}}}{4(\beta_1 - 1)\phi_v}\right)^2, & \tau > \frac{1}{\beta_1 + 1}; \\ \frac{r-\mu}{\rho(1-\tau)}\left(\frac{\beta_1}{\beta_1 - 1}\right)^2, & \text{else;} \end{cases} \tag{11}$$

$$\hat{I}_v^* = \begin{cases} \frac{2\phi_v + \sqrt{4\phi_v^2 - 4\tau\xi_v\phi_v + 2\psi_v{}^2\tau^3 - 2\psi_v\tau\sqrt{[\psi_v{}^2\tau^4 - 4\xi_v\phi_v\tau^2 + 4\phi_v{}^2]}}}{4(\beta_1 - 1)\phi_v}, & x_v > x_0,\ \tau > \frac{1}{\beta_1 + 1}; \\ \frac{1}{\beta_1 - 1}, & x_v > x_0,\ \tau \leqslant \frac{1}{\beta_1 + 1}; \\ \sqrt{\rho\frac{1-\tau}{r-\mu}x_0} - 1, & x_v \leqslant x_0; \end{cases} \tag{12}$$

where $\xi_v = (\beta + \tau - 1), \psi_v = (\beta + \tau - 1)(2\beta - 1), \phi_v = \beta + (\tau - 1)\tau$.

Proof. Similarly, by solving the first-order partial derivatives of the venture capital institutions' objective functions for x_v and I_v, the first-order condition for maximizing them can be obtained as,

$$\begin{cases} \frac{\rho(1-\tau)}{r-\mu}\frac{1}{(I_v + 1)^2}x_v = 1, \\ \frac{\rho(1-\tau)}{r-\mu}\frac{I_v}{I_v + 1}x_v = \frac{\beta_1}{\beta_1 - 1}(I_v - \tau v). \end{cases}$$

By solving this equation system, the optimal investment threshold $\hat{x}_{1v}$ and investment scale $\hat{I}_{1v}$ of venture capital institutions can be obtained as,

$$\hat{x}_{1v} = \begin{cases} \max(x_0, B), & 4\beta_1(\beta_1 - 1)\tau v \leqslant 1; \\ x_0, & \text{else;} \end{cases}$$

$$\hat{I}_{1v} = \begin{cases} \frac{1 + \sqrt{1 - 4\beta_1(\beta_1 - 1)\tau v}}{2(\beta_1 - 1)}, & x_v > x_0; \\ \sqrt{\rho\frac{1-\tau}{r-\mu}x_0} - 1, & x_v \leqslant x_0; \end{cases}$$

where for the simplified result, let $B = \frac{r-\mu}{\rho(1-\tau)}\left(\frac{2\beta_1 - 1 + \sqrt{1 - 4\beta_1(\beta_1 - 1)\tau v}}{2(\beta_1 - 1)}\right)^2$. The government objective is to maximize result. Given the investment timing and investment scale of venture capital institutions, solving the first-order optimal conditions of the function can obtain the government's optimal tax preference ratio at time 2. The first-order derivative of the government objective function is calculated, and the first-order condition for maximizing government objective function is obtained as

$$\frac{2\beta_1 v}{(I+1)(2(\beta_1 - 1)I - 1)} = \frac{1}{1-\tau} - \frac{1}{\beta_1}.$$

The second-order condition is $\tau > \frac{1}{\beta_1 - 1}$. By classifying and discussing the relationship between capital flow x_0 and the investment threshold x_v, and solving the equation, the optimal government tax preference at time 2 is obtained as,

$$v^* = \begin{cases} 0, & \left(\frac{\beta_1}{\beta_1 - 1}\right)^2 < \frac{\rho(1-\tau)}{r-\mu}x_0; \\ \min\{v_{v1}, v_{v2}\}, & \left(\frac{2\beta_1 - 1}{2(\beta_1 - 1)}\right)^2 < \frac{\rho(1-\tau)}{r-\mu}x_0 < \left(\frac{\beta_1}{\beta_1 - 1}\right)^2; \\ v_{v2}, & \text{esle;} \end{cases} \tag{13}$$

where,

$$v_{v1} = \frac{1 - \left(2(\beta_1 - 1)\sqrt{\frac{\rho(1-\tau)}{r-\mu}x_0} - 2\beta_1 + 1\right)^2}{4\tau\beta_1(\beta_1 - 1)},$$

$$v_{v2} = \begin{cases} \frac{2\xi_v\phi_v - \psi_v{}^2\tau^2 + \psi_v\sqrt{[\psi_v{}^2\tau^4 - 4\xi_v\phi_v\tau^2 + 4\phi_v{}^2]}}{8\beta(\beta - 1)\phi_v{}^2}, & \tau > \frac{1}{\beta_1 - 1}; \\ 0, & \tau \leqslant \frac{1}{\beta_1 - 1}. \end{cases}$$

DOI: 10.52396/JUSTC-2022-0011
JUSTC, **2022**, 52(8): 8

To simplify the result, let $\xi_v = (\beta+\tau-1)$, $\psi_v = (\beta+\tau-1)\cdot(2\beta-1)$, $\phi_v = \beta+(\tau-1)\tau$.

By substituting the optimal tax preference v^* into the investment scale $\hat{I}^*_{1v}$ and investment threshold $\hat{x}_{1v}$ of venture capital institutions, and in equilibrium state, the optimal investment threshold $\hat{I}^*_v$ and investment scale $\hat{x}^*_v$ of venture capital institutions can be obtained.

3 The effect of the value uncertainty of the enterprise on the optimal decision-making of venture capital and government incentives

In Section 2, the analytical solutions for the optimal decisions of venture capital institutions and the government are obtained when the options game between the two reaches an equilibrium state. Based on this optimal solution, this section will further reveal the influence of the value uncertainty of entrepreneurial enterprises on the optimal decision-making of venture capital institutions and government incentives under risk subsidy and tax policies.

3.1 The effect of the value uncertainty and incentive policies on the optimal investment timing of venture capital institutions

Based on the analytical formula for the optimal investment threshold of venture capital institutions under the equilibrium state of the two investment incentive policies obtained above, the further analysis aims to reveal the relationship between the uncertainty of enterprise value and the investment timing of venture capital institutions under the two investment incentive policies, compare the investment opportunities of venture capital institutions under the two investment incentive policies, and explore the comparison of the implementation effects of the two investment incentive policies in terms of accelerating the investment process of venture capital institutions. The research conclusions are presented in Theorems 3.1 and 3.2, respectively.

Theorem 3.1. When the government adopts risk subsidy policies and preferential tax policies, the investment threshold $\hat{x}_s$, $\hat{x}_v$ of venture capital institutions increases with an increase in the value uncertainty of the entrepreneurial enterprise; that is, the uncertainty of the entrepreneurial enterprise value delays the investment timing of venture capital institutions.

The theorem shows that the greater the uncertainty of the enterprise value, the greater the enterprise's risk, Venture capital institutions need to conduct more data review and discussion before investing, and the investment attitude will be more prudent, which will be reflected in delayed investment.

Proof. First discuss the relationship between uncertainty and β_1.

Let $m = \dfrac{1}{\sigma^2}$, $\dfrac{\partial\beta_1}{\partial m} = -\mu + \dfrac{r+\mu(-0.5+m\mu)}{\sqrt{2rm+(-0.5+m\mu)^2}}$, then let $\dfrac{\partial\beta_1}{\partial m} = 0$, and let $r=\mu$. By assuming that $r>\mu$, $\dfrac{\partial\beta_1}{\partial m} > 0$, the larger m is, the bigger β_1, or the smaller σ^2 is, the larger β_1.

Second, we discuss the relationship between uncertainty and the investment threshold $\hat{x}_s$. When $\tau > \dfrac{1}{\beta_1+1}$,

$$\hat{x}_s = \frac{r-\mu}{\rho(1-\tau)}\left(\frac{(2\beta_1-1)2\xi-\psi^+\sqrt{[\psi^2+4\xi(1-\tau)\beta]}}{4(\beta_1-1)\xi}\right)^2,$$

$$h_1 = \frac{\rho}{r-\mu}\hat{x}_s = \frac{1}{(1-\tau)}\left(\frac{(2\beta_1-1)2\xi-\psi+\sqrt{[\psi^2+4\xi(1-\tau)\beta]}}{4(\beta_1-1)\xi}\right)^2.$$

We obtain the partial derivative of h_1 to β_1. The positive and negative conditions of the partial derivative cannot be obtained using the analytical formula of the partial derivative, as well as the relationship between uncertainty σ^2 and the investment threshold $\hat{x}_s$. Therefore, Mathematica software is used to obtain all extreme values of the partial derivative under the condition of $\dfrac{1}{\beta_1+1} < \tau < 1$ and $\beta_1 > 1$ to determine the positive and negative results of partial derivatives. Its maximum value is close to $-2.2148696508\times10^{10}$; thus $\dfrac{\partial h_1}{\partial\beta_1}$ is always negative. That is, the bigger β_1 is, the smaller $h_1 = \dfrac{\rho}{r-\mu}\hat{x}_s$, the smaller σ^2 is, the smaller $\hat{x}_s$.

When $\tau < \dfrac{1}{\beta_1+1}$, $\hat{x}_s = \dfrac{r-\mu}{\rho(1-\tau)}\left(\dfrac{\beta_1}{\beta_1-1}\right)^2$, $\dfrac{\partial\hat{x}_s(s)}{\partial\beta_1} = -\dfrac{2\beta_1}{(\beta_1-1)^3}\dfrac{r-\mu}{\rho(1-\tau)}$ is always negative, and the bigger σ^2, the smaller β_1, the larger $\hat{x}_s$.

In summary, regardless of the uncertainty, the investment threshold $\hat{x}_s$ shows an increasing trend along with the increase in uncertainty; that is, the uncertainty of the venture enterprise project value delays the investment timing of venture capital institutions.

Finally, the proof of the relationship between uncertainty and investment threshold $\hat{x}_v$ is the same as above and will not be repeated here.

Theorem 3.2. When the value uncertainty of the entrepreneurial enterprise is less than threshold I, that is $\sigma^2 < f^{-1}\left(\dfrac{1}{\tau}-1\right)$, the preferential tax policy is more effective than the risk subsidy policy in accelerating investment timing. When the uncertainty is greater than threshold I, that is, $\sigma^2 \geqslant f^{-1}\left(\dfrac{1}{\tau}-1\right)$, the two investment incentive policies have the same effect in accelerating the investment timing.

The theorem shows that when the uncertainty of the enterprise value is less than threshold I, the value of the entrepreneurial enterprise is relatively stable, and it is usually in the late stage of development of the start-up enterprise, which means that the actual value of the project is already good [29,30]. Since the degree of tax reduction depends on the tax reduction rate and the project value, the expected tax reduction at this time is likely to be greater than the one-time subsidy. Therefore, under the tax incentive policy, the optimal investment threshold for venture capital institutions is lowered, thereby accelerating investment timing. When uncertainty is greater than threshold I, the underpaid taxable income τv and the risk subsidy s have almost the same effect on reducing the investment cost of venture capital institutions, so the incentive effect of the two policies in accelerating investment is the same.

DOI: 10.52396/JUSTC-2022-0011
JUSTC, 2022, 52(8): 8

Proof. To compare the two investment thresholds under the risk subsidy and tax preferential policies, let $h_3 = \hat{x}_s - \hat{x}_v$.

When $\tau > \dfrac{1}{\beta_1+1}$,

$$\frac{\rho(1-\tau)}{r-\mu}h_3 = \left(\frac{(2\beta_1-1)2\xi-\psi+\sqrt{[\psi^2+4\xi(1-\tau)\beta]}}{4(\beta_1-1)\xi}\right)^2 - \left(\frac{(2\beta_1-1)2\phi_v+\sqrt{4\phi_v^2-4\tau\xi_v\phi_v+2\psi_v^2\tau^3-2\psi_v\tau\sqrt{[\psi_v^2\tau^4-4\xi_v\phi_v\tau^2+4\phi_v^2]}}}{4(\beta_1-1)\phi_v}\right)^2.$$

Mathematica software was used to obtain all the extremum which is $\dfrac{(2\beta_1-1)2\xi-\psi+\sqrt{[\psi^2+4\xi(1-\tau)\beta]}}{4(\beta_1-1)\xi}$ and the minimum value is close to 2.0000001218209085. Then the analytical expression in the first parenthesis is always positive, so only by comparing the difference between the expressions in the two parentheses do we obtain the size relationship between the investment thresholds under the two policies.

$$m_2 = \frac{(2\beta_1-1)2\xi-\psi+\sqrt{[\psi^2+4\xi(1-\tau)\beta]}}{4(\beta_1-1)\xi} - \frac{(2\beta_1-1)2\phi_v}{4(\beta_1-1)\phi_v} - \frac{\sqrt{4\phi_v^2-4\tau\xi_v\phi_v+2\psi_v^2\tau^3-2\psi_v\tau\sqrt{[\psi_v^2\tau^4-4\xi_v\phi_v\tau^2+4\phi_v^2]}}}{4(\beta_1-1)\phi_v}.$$

According to the analytical formula, it is impossible to judge the positive and negative conditions of m_2, so using Mathematica software, to find the minimum value of m_2 under the conditions of $\dfrac{1}{\beta_1+1} < \tau < 1$ and $\beta_1 > 1$, and found that the minimum value of m_2 is close to 0.44133845908684277, which is greater than zero. In other words, $h_3 > 0$, $\hat{x}_s > \hat{x}_v$.

Regardless of the uncertainty σ^2 of the entrepreneurial enterprise value, the investment threshold x_s under the risk subsidy policy is higher than x_v under the preferential tax policy, indicating that the preferential tax policy is more effective than the risk subsidy policy in accelerating investment timing.

When $\tau \leqslant \dfrac{1}{\beta_1+1}$, $\hat{x}_s = \hat{x}_v \dfrac{r-\mu}{\rho(1-\tau)}\left(\dfrac{\beta_1}{\beta_1-1}\right)^2$, at this time, regardless of how much uncertainty σ^2 of entrepreneurial enterprise value is, the investment thresholds under the two preferential policies are equal. At this time, the two preferential policies have the same effect on accelerating investment timing.

3.2 The effect of the value uncertainty and incentive policies on the optimal investment scale of venture capital institutions

This section reveals the relationship between the uncertainty of entrepreneurial enterprise value and the investment scale of venture capital institutions under the two investment incentive policies by comparing the implementation effects of the two investment incentive policies. The research conclusions are as follows: Theorems 3.3 and 3.4.

Theorem 3.3. When the government adopts risk subsidy policies or preferential tax policies, if the venture capital institution does not invest immediately, that is $\hat{x}_s > x_0$, $\hat{x}_v > x_0$, its investment scale $\hat{I}_s$, $\hat{I}_v$ increased with the increasing of the uncertainty of the entrepreneurial enterprise value, that is, the value uncertainty of entrepreneurial enterprise at this time increased the investment scale of the venture capital institution; if the venture capital institution chooses to invest immediately, that is $\hat{x}_s \leqslant x_0$, $\hat{x}_v \leqslant x_0$, its investment scale $\hat{I}_s$, $\hat{I}_v$ is not affected by the uncertainty, that is, the uncertainty of the entrepreneurial enterprise value does not affect the investment scale of the entrepreneurial enterprise investment institution at this time.

The theorem shows that if the venture capital institution does not invest immediately, the increase in the uncertainty of the institution's value will increase its optimal investment scale. This is because an increase in value uncertainty implies an increase in the likelihood that the value will increase. At this time, increasing the scale of investment can better ensure the capital demand for the enterprise, ensure the increase in the enterprise value, and then achieve the optimal income goal of the venture capital institution. Therefore, the venture capital institution will increase the investment scale on the premise of a prudent attitude. If a venture capital institution chooses to invest immediately, its investment decision is only related to the current project capital flow and has nothing to do with other quantities. Therefore, the investment scale of the venture capital institution is not affected by the uncertainty of the entrepreneurial enterprise value.

Proof. First discuss the relationship between uncertainty and the investment scale $\hat{I}_s$.

When $\hat{x}_s > x_0$, $\tau > \dfrac{1}{\beta_1+1}$,

$$\hat{I}_s = \frac{2\xi-\psi+\sqrt{\psi^2+4\xi\beta_1(1-\tau)}}{4\xi(\beta_1-1)}.$$

By using Mathematica software to obtain the partial derivative $\hat{I}_s$ to β_1, it is impossible to judge whether the partial derivative is positive or negative according to the analytical formula. Therefore, using Mathematica software to find the maximum value of the partial derivative under the condition of $\dfrac{1}{\beta_1+1} < \tau < 1$ and $\beta_1 > 1$, which is always less than zero, and its maximum value is close to $-7.261526967643237\times10^{-10}$; that is, the smaller σ^2 is, the larger β_1, the smaller $\hat{I}_s$.

When $\hat{x}_s > x_0$, $\tau \leqslant \dfrac{1}{\beta_1+1}$, $\hat{I}_s = \dfrac{1}{\beta_1-1}$; that is, the smaller σ^2, the larger β_1, and the smaller $\hat{I}_s$. When $\hat{x}_s \leqslant x_0$, $\hat{I}_s = \sqrt{\rho\dfrac{1-\tau}{r-\mu}x_0} - 1$, at this time there is no relationship between investment scale and uncertainty.

In summary, when $\hat{x}_s > x_0$, venture capital institutions will not invest immediately, and their investment scale $\hat{I}_s$ increases with an increase in uncertainty. At this time, the uncertainty of the venture enterprise project value increases the investment scale of venture capital institutions; when $\hat{x}_s \leqslant x_0$,

DOI: 10.52396/JUSTC-2022-0011
JUSTC, **2022**, 52(8): 8

venture capital institutions will choose to invest immediately, and the investment scale $\hat{I}_s$ has nothing to do with uncertainty, that is, the uncertainty of the venture enterprise project value at this time does not affect the investment scale of the venture capital institution.

Second, the proof of the relationship between uncertainty and investment scale $\hat{I}_v$ is the same as above, and will not repeat the discussion.

Theorem 3.4. When venture capital institutions do not invest immediately, that is, $\hat{x}_s > x_0$, $\hat{x}_v > x_0$, investment decisions are affected by investment incentive policies. When the uncertainty is less than threshold I, that is $\sigma^2 < f^{-1}\left(\frac{1}{\tau}-1\right)$, the risk subsidy policy is more effective than the preferential tax policy in increasing the investment scale of venture capital institutions. When the uncertainty is greater than threshold I, that is $\sigma^2 \geqslant f^{-1}\left(\frac{1}{\tau}-1\right)$, the two investment incentive policies have the same effect in increasing the investment scale of venture capital institutions.

The theorem shows that if the venture capital institution does not invest immediately, the investment scale is affected by the incentive policy, and the impact of different incentive policies is controlled by the uncertainty of the project. Specifically, when the uncertainty is small, it can be seen from Theorem 3.2 that the investment threshold under the risk subsidy policy is high, which means a more cautious project qualification review[31], which can guarantee a higher probability of project benefits[32], then venture capital institutions are willing to give higher investment scale. When uncertainty is relatively large, the risk subsidy and preferential tax policies have the same effect in accelerating investment timing, and the corresponding incentive effect in increasing the investment scale is also the same.

Proof. In order to compare the two investment scales under the risk subsidy and tax preferential policies, let $h_4 = \hat{I}_s - \hat{I}_v$.

When $\hat{x}_s > x_0$, $\hat{x}_v > x_0$, $\tau > \frac{1}{\beta_1+1}$,

$$h_4 = \frac{2\xi-\psi+\sqrt{\psi^2+4\xi\beta_1(1-\tau)}}{4\xi(\beta_1-1)} - \frac{2\phi_v}{4(\beta_1-1)\phi_v} - \frac{\sqrt{4{\phi_v}^2-4\tau\xi_v\phi_v+2{\psi_v}^2\tau^3-2\psi_v\tau\sqrt{[{\psi_v}^2\tau^4-4\xi_v\phi_v\tau^2+4\phi_v^2]}}}{4(\beta_1-1)\phi_v}.$$

From Theorem 3.1, it can be seen that m_2 is always positive, $h_4 > 0$, $\hat{I}_s > \hat{I}_v$. In other words, regardless of the value of project uncertainty σ^2, the investment scale $\hat{I}_s$ under the risk subsidy policy is higher than $\hat{I}_v$ under the preferential tax policy, indicating that the risk subsidy policy is more effective than the preferential tax policy in increasing the investment scale of venture capital institutions.

When $\hat{x}_s > x_0$, $\hat{x}_v > x_0$, $\tau \leqslant \frac{1}{\beta_1+1}$,

$$\hat{I}_s = \hat{I}_v = \frac{1}{\beta_1-1}.$$

When $\hat{x}_s < x_0$, $\hat{x}_v < x_0$,

$$\hat{I}_s = \hat{I}_v = \sqrt{\rho\frac{1-\tau}{r-\mu}x_0} - 1,$$

at this time $h_4 = 0$, it shows that in this case, no matter how much the uncertainty σ^2 of the project is, the investment scale under the two preferential policies will always be the same. At this time, in terms of increasing the investment scale of venture capital institutions, the two preferential policies have the same effect.

4 Numerical simulation

Section 3 describes the relationship between the optimal investment decisions of venture capital institutions and the uncertainty of entrepreneurial enterprises' value in the government's optimal investment incentive policy through mathematical proof and analysis. On this basis, this section further interprets the conclusions of Section 3 through numerical simulations. Numerical simulations are performed according to the numerically determined parameters commonly found in existing studies (e.g., Lukas and Thiergart[28], Wong[33], Danielova and Sarkar[34]). This study takes $r = 0.08$, $\mu = 0.04$, $\tau = 0.35$, $x_0 = 0.06$, $\rho = 0.3$.

4.1 The influence of the value uncertainty on the optimal investment timing of venture capital institutions.

To intuitively describe the laws revealed by Theorems 3.1 and 3.2, we explore the relationship between the optimal investment threshold of venture capital institutions and the uncertainty σ^2 of the entrepreneurial enterprise value, and follow the optimal investment threshold of venture capital institutions under the risk subsidy policy and preferential tax policy. the changes in project uncertainty are plotted in a line chart for comparison in Fig. 2. The solid line represents the optimal investment threshold for venture capital institutions under the preferential tax policy, and the dotted line represents the optimal investment threshold for venture capital institutions under the risk subsidy policy.

As shown in Fig. 2, with an increase in project uncertainty σ^2, the investment threshold x under the two policies increases, indicating that the uncertainty of the project value of entrepreneurial enterprises has delayed the investment timing of venture capital institutions to a certain extent.

At this time $\tau = 0.35$, within the range of $\sigma^2 \in (0, 0.08)$, which satisfies $\sigma^2 < f^{-1}\left(\frac{1}{\tau}-1\right)$, regardless of the value of project uncertainty σ^2, the investment threshold under the risk subsidy policy is significantly higher than that under the preferential tax policy. This indicates that preferential tax policies are more effective when accelerating investment timing than risk subsidy policies.

Within the range $\sigma^2 \in (0.08, 0.3)$, which satisfies with $\sigma^2 \geq f^{-1}\left(\frac{1}{\tau}-1\right)$, the optimal investment thresholds under the risk subsidy and preferential tax policies are equal. At this time, the two policies have the same effect on accelerating investment timing.

DOI: 10.52396/JUSTC-2022-0011
JUSTC, 2022, 52(8): 8

4.2 The influence of the value uncertainty on the optimal investment scale of venture capital institutions

To intuitively describe the laws revealed by Theorem 3.3 and Theorem 3.4, changes in the optimal investment scale of venture capital institutions along with project uncertainty σ^2 under the risk subsidy policy and the preferential tax policy are drawn in a line chart for comparison, as shown in Fig. 3. The solid line represents the optimal investment scale of venture capital institutions under the preferential tax policy, and the dotted line represents the optimal investment scale of venture capital institutions under the risk subsidy policy.

As shown in Fig. 3, as project uncertainty σ^2 increases, the scale of investment I under the two policies increases, indicating that project uncertainty increases the investment scale of venture capital institutions to a certain extent.

At this time, $\tau = 0.35$, within the range of $\sigma^2 \in (0, 0.08)$, which satisfies $\sigma^2 < f^{-1}\left(\frac{1}{\tau} - 1\right)$, regardless of the extent to which the project uncertainty σ^2 is the investment scale under the risk subsidy policy is significantly higher than that under the preferential tax policy, indicating that the risk subsidy policy is more effective in promoting venture capital institutions to increase their investment scale.

Within the range $\sigma^2 \in (0.08, 0.3)$, which satisfies $\sigma^2 \geq f^{-1}\left(\frac{1}{\tau} - 1\right)$, the optimal investment scales under the two investment incentive policies are equal. At this time, the two policies have the same effect in promoting venture capital institutions to increase their investment scales.

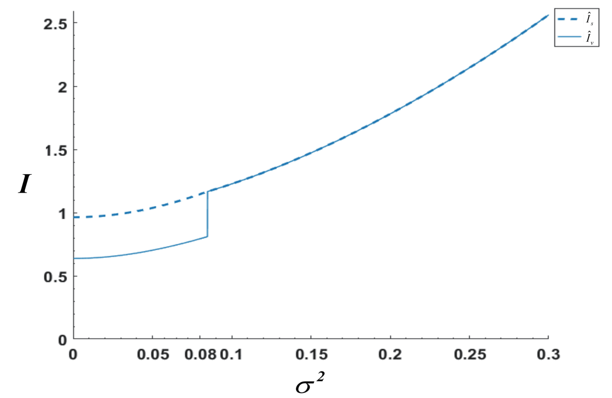


Fig. 3. The optimal investment scale and project uncertainty of venture capital institutions.

5 Conclusions

This study finds that uncertainty in the value of entrepreneurial enterprises delays the investment timing of venture capital institutions. When the uncertainty of the value of the invested enterprise is small, the preferential tax policy is more effective than the risk subsidy policy in accelerating the investment timing; otherwise, the two investment incentive policies have the same effect. In terms of increasing the investment scale of venture capital institutions, if venture capital institutions do not invest immediately, the uncertainty of the venture enterprise project will increase the investment scale of venture capital institutions. If the venture capital institution chooses to invest immediately, its investment scale will not be affected by the value of the venture capital. If venture capital institutions do not invest immediately when the uncertainty of the project is less than the threshold, the risk subsidy policy is more effective than the preferential tax policy in increasing the investment scale of venture capital institutions; otherwise, the two investment incentives have the same effect. Therefore, risk subsidies and tax incentives for venture capital have advantages in terms of the timing and scale of promoting venture capital into the innovation market. In practical application, when there are tax reductions or risk subsidy policies, the venture capital institutions determine the investment timing and scale according to the uncertainty value of the investment project and the intensity of the incentive policies. Policymakers can formulate incentive policies based on the risks of innovation and entrepreneurship and the intensity of the incentives they want to achieve.

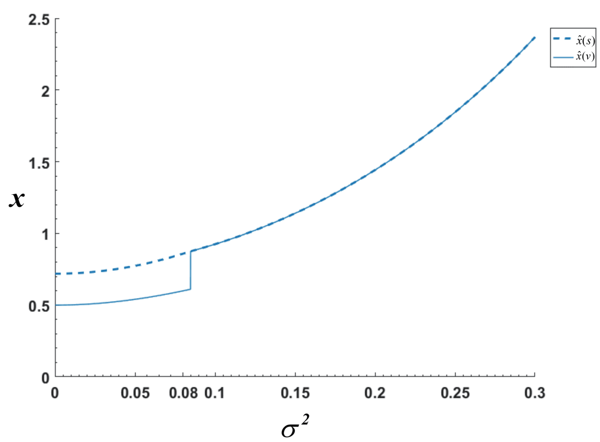


Fig. 2. The optimal investment threshold and project uncertainty of venture capital institutions.

Acknowledgements

This work was supported by the National Social Science Fund of China (21BJL043), National Natural Science Foundation of China (72104034), Humanities and Social Science Fund of Ministry of Education of China (21YJC630037), General Project of Shaanxi Soft Science Research Program (2022KRM155), China Postdoctoral Science Foundation (2022T150072) and Fundamental Research Funds for the Central Universities, CHD (300102232615).615).

Conflict of interest

The authors declare that they have no conflict of interest.

Biographies

Wenjun Yan received her Ph.D. degree in Business Administration from Xi'an Jiaotong University in 2012. She is currently an associate professor in Chang'an University. Her major research interests focus on investment decision of venture capital and risk management of public capital.

Haonan He received his Ph.D. degree in Business Administration from the University of Science and Technology of China in 2019. He is currently a lecturer in Chang'an University. His research mainly focuses on innovation incentive policies.

References

[1] Zhou H T, Zhang Z G. The impact of governmental R&D investment on business technological innovation decision behavior-evidence from the micro-data of Guangdong enterprises. *China Soft Science,* **2016** (6): 110–120.

[2] Lin M X, Zhang Z W, He J. R&D support policy choice, institutional environment and enterprise R&D investment. *Shanghai Journal of Economics,* **2018**, *9*: 35–48.

[3] Zuo Z G, Shi F Z, Tan G Q. Does state-owned venture capital play a "crowding-in" role? An empirical research based on certification mechanism. *Journal of Finance and Economics,* **2017**, *43* (12): 17–29.

[4] Wang J, Wu H Q, Zhang C, et al. The evaluation mechanism and influencing factors of profitability of sci-tech innovation enterprises. *Studies in Science of Science,* **2020**, *38* (1): 124–132.

[5] Huang L C, Teng X D, Miao H, et al. The evaluation of balance between innovation incentives and responsible innovation in innovation policy. *China Soft Science,* **2018** (5): 25–38.

[6] Huang J Y, Cao Y F, Zhou H L, et al. Optimal investment timing and scale choice of overseas oil projects: A real option approach. *Energies,* **2018**, *11* (11): 2954.

[7] Wang Y C, Qian Y C. Market reaction to tender offers: Insights from China. *JUSTC,* **2021**, *51* (12): 894–911.

[8] Dai X Y, Chapman G, Shen H. Late-stage venture capital and firm performance: Evidence from small and medium-sized enterprises in China. *Applied Economics,* **2022**, *54* (20): 2356–2372.

[9] Wang X P, Qie S Y. Research on the timing of CCS investment in supply chain under carbon emission trading. *Journal of Industrial Engineering and Engineering Management,* **2020**, *34* (2): 124–130.

[10] Wang G G, Xie F J, Jia Y. Reconsider incentive mechanism of R&D subsidy policy-based on exploration for external financing incentive mechanism. *Industrial Economics,* **2017** (2): 60–78.

[11] Li J X, Wen X N. Research on the relationship between the allocation efficiency and influencing factors of China's science and technology finance. *China Soft Science,* **2019** (1): 164–174.

[12] Sendstad L H, Chronopoulos M. Sequential investment in renewable energy technologies under policy uncertainty. *Energy Policy,* **2020**, *137*: 111152.

[13] Zhou Y, Pan Y. Subsidization and tax reduction: The policy choice of new energy vehicles under the constraints of transaction costs. *Journal of Management World,* **2019**, *35* (10): 133–149.

[14] Agénor P R, Neanidis K C. Innovation, public capital, and growth. *Journal of Macroeconomics,* **2015**, *44*: 252–275.

[15] Lin B Q, Luan R R. Do government subsidies promote efficiency in technological innovation of China's photovoltaic enterprises? *Journal of Cleaner Production,* **2020**, *254*: 120108.

[16] Chen S L, Huang Z H, Drakeford B M, et al. Lending Interest rate, loaning scale, and government subsidy scale in green innovation. *Energies,* **2019**, *12* (23): 4431.

[17] Alperovych Y, Hübner G, Lobet F. How does governmental versus private venture capital backing affect a firm's efficiency? Evidence from Belgium. *Journal of Business Venturing,* **2015**, *30* (4): 508–525.

[18] Jung S H, Feng T. Government subsidies for green technology development under uncertainty. *European Journal of Operational Research,* **2020**, *286* (2): 726–739.

[19] Redonda A, Diaz de Sarralde S, Hallerberg M, et al. Tax expenditure and the treatment of tax incentives for investment. *Economics,* **2019**, *13* (1): 20190012.

[20] Zhao L M, Chen Y Q. Optimal subsidies for green products: A maximal policy benefit perspective. *Symmetry,* **2019**, *11* (1): 63.

[21] Zhao A W, Guan H J. Simulation and analysis of optimal policy combination for incentive of enterprise environmental technology innovation. *Journal of Management Science,* **2018**, *31* (6): 104–116.

[22] Xu Y, Meng Y P. Evolution game between government and port enterprises under mandatory emission reduction. *JUSTC,* **2019**, *49* (9): 762–772.

[23] Liang X, Fu Y. Study on the supply side evolutionary game of green building under the mechanism of government dynamic reward and punishment. *Chinese Journal of Management Science,* **2020**, *29* (2): 184–194.

[24] Liu C Y, Xia T S, Yu T. Research on evolutionary game of government regulation and production of manufacturer in the angle of low carbon. *Chinese Journal of Management Science,* **2019**, *27* (11): 96–106.

[25] Zhang H J, Yu H Y, Li C Y. Incentive contract design and optimization of government subsidies policy in the closed-loop supply chain. *Chinese Journal of Management Science,* **2016**, *24* (8): 71–78.

[26] Wu B H T, Mazur M. Managerial incentives and investment policy in family firms: Evidence from a structural analysis. *Journal of Small Business Management,* **2018**, *56* (4): 618–657.

[27] Abbiati L, Antinyan A, Corazzini L. A survey experiment on information, taxpayer preferences, and perceived adequacy of the tax burden. *Heliyon,* **2020**, *6* (3): e03576.

[28] Lukas E, Thiergart S. The interaction of debt financing, cash grants and the optimal investment policy under uncertainty. *European Journal of Operational Research,* **2019**, *276* (1): 284–299.

[29] Wang W Q, Ma H J. Technology proximity, R&D investment and innovation performance in technology mergers and acquisitions-from a perspective of corporate life cycle. *Management Review,* **2020**, *32* (6): 104–113.

[30] Ma S, Gao L M, Zhao G H. Bootstrap-DEA model oriented study on the theory of enterprise life cycle phase. *China Soft Science,* **2019** (11): 176–182.

[31] Chang Y N, Wang S J. Profit allocation of PPP project from the perspective of incentives: The case of Chinese enterprises' investment in the infrastructure projects of GMS countries under the support of Asian Infrastructure Investment Bank. *Management Review,* **2018**, *30* (11): 257–265.

[32] Li B X, Qiao J M, Niu X Q, et al. Game analysis of managers' selection of long or short-term investment project from the perspective of managerial entrenchment. *Management Review,* **2019**, *31* (1): 197–205.

[33] Wong K P. On the neutrality of debt in the investment intensity. *Annals of Finance,* **2010**, *6*: 335–356.

[34] Danielova A, Sarkar S. The effect of leverage on the tax-cut versus investment-subsidy argument. *Review of Financial Economics,* **2011**, *20* (4): 123–129.

DOI: 10.52396/JUSTC-2022-0011
JUSTC, **2022**, 52(8): 8