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Game analysis on synergy of the industry-university-research based on double principal-agent

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ABSTRACT

There exsits the double principal-agent in the Industry-University-Research(IUR) cooperation. A principal-agent model of the IUR synergy is set up through introducing the individual rationality constraint and incentive compatibility, to demonstrate the inevitability of the existence of moral hazard and the necessity of the design of incentive contract in the IUR synergy cooperation,point out that the relevant parameters could be determined to design contract mechanism to improve the efficiency of the IUR synergy.

KEYWORDS

Industry-university-research; Synergy; Double principal-agent; Game; Incentive.

INTRODUCTION

The Industry-University-Research synergy can effectively combine the main utility of the enterprises, universities and research institutions,sharing the advantages of resources, to promote the technological innovation and achievement transformation, which creates a multi-win situation. The IUR synergy is a relationship of double principal-agent,the enterprise gives the research project to the research,which constitutes the first principal-agent, the research does not assume or partly undertakes research tasks, and combines the university to constitute the second one. The three parties constantly adjust their strategies based on information in different stages of their collaboration, to realize the goal of optimization, which belongs to the bounded rational game. That is to say, any party in the IUR synergy could not cooperate or breach of promise for their own interests, damage the another interests, there esxits incentive compatibility and moral hazard. Guo Jianluan(2004) thinks that the information asymmetry causes adverse selection and double principal-agent problem[1]. Zhang Mier and Wu Chunyou(2001) discusses the information asymmetry in IUR cooperation from the point of technology investment,and the resulting moral hazard problem[2]. Zhang Guoxing(2013) analyzes the establishment of contract incentive program under the incomplete information condition based on the principal-agent game model,to solve the problem of adverse selection of the contract[3]. Mirrlees(1976)uses the principal-agent model to study the incentive and risk, providing the idea of solving the problem[4]. The study result of Yu Lei and Xue Huifeng(2007)is that, the key of the principal-agent is to design constraint incentive mechanism to solve the agent's risk[5]. Li Yueheng(2008) puts forward the control plan of the rent-seeking behavior of the College teachers in the condition of the principal-agent, which can be summarized as supervision, encouragement and punishment[6].Xin Aifang(2005) affirms the existence of moral hazard, which makes the IUR cooperative parties have preferences in the choice of cooperation mode[7]. Zhan Meiqiu and Pan Jieyi(2008) establish the profit distribution model of the university-industry cooperation, discusses the contract mechanism and the estimation method of related parameters[8]. Huang Wei(2013) analyzes the formation conditions and modes of synergetic innovation under the guidance fund mode, shows that the innovation subject should abide by the contract and get the fixed interest[9].

The existing literature more analyze single the principal-agent applyment and related mechanisms in IUR cooperation, but ignore the double principal-agent problem in the IUR synergy innovation. Game models of the IUR synergy in the condition of symmetric information and asymmetric information are established based on the principal-agent theory, to explore how to design constraint and incentive strategy in terms of different parameters,in order to avoid risks and promote the smooth implementation of the IUR synergy innovation.

GAME MODELS OF THE IUR SYNERGY BASED ON DOUBLE PRINCIPAL-AGENT

Basic hypothesis

In the double principal-agent of the IUR synergy, the industry does not supervise the project process, but constraints the partner's behavior through the contract. Considering that the research is the direct project assignor, do not participate in the R & D, and supervise the implementation of the university. Here,the industry is the principal, the university is the agent,the research is not only the principal,but also the agent. It can be given that:

U and R represent the university and the research respectively. U's work has the uncertainty and its output is a uncertainty function of the effort level,which is given as one-dimensional variable a. The effort cost $c(\mathrm{U})$ is equivalent to the cost of money,increasing with a, $c(U)=\frac{1}{2}\lambda_1 a^2$, λ_1 is the effort cost coefficient of U and λ_1>0.

The profit of the industry π is linear correlated with a, $\pi = a+\theta$, θ is a random variable, $\theta \sim N(0,\sigma^2)$ because of uncertainty of the natural state. a will affect the mean of π,but will not affect its variance, $E(\pi)=E(a+\theta)=a, \mathrm{var}(\pi)=\sigma^2$.

R supervises U to enhance the cooperation effectiveness. Given the supervision cost is $c(R)$, and will also affect the industry's benefit. Given $c(R)=\frac{1}{2}\lambda_2\pi^2=\frac{1}{2}\lambda_2(a+\theta)^2$, λ_2 is the effort cost coefficient of R and λ_2>0.

Because the industry couldn't control the university's work,and the effot of U directly affects the benefit of the enterprise,so,the enterprise can control the funding to constraint the research, and thus indirectly constraint the university. The industry can invest regularly or relate the net inflow of money with the future benefit. Given I is the investment of the industry which is related with its profit,it is that $I=\frac{1}{2}\lambda_3\pi^2=\frac{1}{2}\lambda_3(a+\theta)^2$, λ_3 is the correlation coefficient of I and π, λ_3 >0.

k is the incentive factor. The principal-agent between the industry and the reseach is based on the standard contract, which sets the proportion of revenue sharing k. The revenue of the research is $k\pi$,0< k <1.

The principal-agent between U and R is based on the linear contract which sets the proportion of revenue sharing γ. The revenue of U is $\gamma k\pi$,0< γ <1.

The enterprise and the research are risk-neutral, the university is risk-averse and its utility function is $u=-e^{-\rho w}$, ρ is Is a measure of absolute risk-averse, w is the real income.

Principal-agent model of the UIR synery under symmetric information

v_1 and v_2 represent the expected utility of the industry and the research. The expected income is equal to the expected utility for the point of the risk-neutral. There are:

$$Ev_1[(1-k)\pi - I] = E[(1-k)\pi - \frac{1}{2}\lambda_3\pi^2] = (1-k)a - \frac{1}{2}\lambda_3(\sigma^2 + a^2)$$

$$Ev_2[k\pi + I - \gamma k\pi - c(R)] = E(k\pi + \frac{1}{2}\lambda_3\pi^2 - \gamma k\pi - \frac{1}{2}\lambda_2\pi^2)$$
$$= (1-\gamma)ka + \frac{1}{2}(\lambda_3 - \lambda_2)(\sigma^2 + a^2)$$

The university is risk-adverse and its risk cost is $\frac{1}{2}\rho\gamma^2\sigma^2$,the certainty equivalence is: $Ew - \frac{1}{2}\rho\gamma^2\sigma^2 = E[\gamma k\pi - \mathrm{c}(U)] - \frac{1}{2}\rho\gamma^2\sigma^2 = \gamma ka - \frac{1}{2}\lambda_1 a^2 - \frac{1}{2}\rho\gamma^2\sigma^2$ The goal of the industry and the research is to maximize $Ev_i(\mathrm{i}=1,2)$,the one of the university is to maximize Ew. Given the reservation utility is w_0, therefore the individual rationality constraint (IR) of the university can be expressed as:

$$Ew - \frac{1}{2}\rho\gamma^2\sigma^2 = \gamma ka - \frac{1}{2}\lambda_1 a^2 - \frac{1}{2}\rho\gamma^2\sigma^2 \geq w_0$$

For the university, only the certainty equivalent income is not lower than the reservation utility can U cooperate with R. When R could observe the behavior of U in the principal-agent of the U - R, the incentive compatibility constraint (IC) is redundant[10]. At this time, the problem of R is how to select the parameters to optimize their income. That is:

$$\max_{\gamma,a} Ev_2 = \max_{\gamma,a}(1-\gamma)ka + \frac{1}{2}(\lambda_3 - \lambda_2)(\sigma^2 + a^2)$$

$$s.t.(IR)\gamma a - \frac{1}{2}\lambda_1 a^2 - \frac{1}{2}\rho\gamma^2\sigma^2 \geq w_0 \quad \textbf{(1)}$$

Obviously, R hopes that U contract with the reservation utility, That is, IR equation was established:

$$\gamma a - \frac{1}{2}\lambda_1 a^2 - \frac{1}{2}\rho\gamma^2\sigma^2 = w_0 \quad \textbf{(2)}$$

Joint(1)and(2)to get the answer:

$$a = \frac{k}{\lambda_1 + \lambda_2 - \lambda_3}, \gamma = 0$$

When the expected income is maximal:

$$\frac{\partial Ev_1}{\partial a} = (1-k) - a\lambda_3 = 0 \quad a = \frac{1-k}{\lambda_3}$$

Compare $\frac{k}{\lambda_1+\lambda_2-\lambda_3}$ and $\frac{1-k}{\lambda_3}$, it can be found that,when parameters k , λ_1, λ_2 and λ_3 value diffirently, $\frac{k}{\lambda_1+\lambda_2-\lambda_3} \le \frac{1-k}{\lambda_3}$ and $\frac{k}{\lambda_1+\lambda_2-\lambda_3} \ge \frac{1-k}{\lambda_3}$ just might be able to.

Principal-agent model of the UIR synery under asymmetric information

In general, R could not always supervise the behavior of U and information asymmetry exists inevitably. It means that when the effort degree of U is not observable, the principal-agent of the U - R belongs to incomplete information game. If U doesn't bear any risk, $\gamma = 0$,U can only choose to ensure its own interests obviously. In the model there exsits the moral risk of hidding action, so the problem of the principal is how to combine the interests of the agent to incentive improving the effort level. At this time, R should use IC . Given that $a=\frac{\gamma}{\lambda_1}$, R makes γ to get revenue optimization.

$$\max_{\gamma} Ev_2 = \max_{\gamma}(1-\gamma)ka + \frac{1}{2}(\lambda_3-\lambda_2)(\sigma^2+a^2)$$

$$s.t.(IR)\gamma ka - \frac{1}{2}\lambda_1 a^2 - \frac{1}{2}\rho\gamma^2\sigma^2 \ge w_0 \quad \textbf{(3)}$$

$$(IC) \qquad a = \gamma / \lambda_1 \quad \textbf{(4)}$$

Joint(3)and(4)to get the answer:

$$a = \frac{k}{\lambda_1{}^2\rho\sigma^2+\lambda_1+\lambda_2-\lambda_3}$$

$$\gamma = \frac{\lambda_1 k}{\lambda_1{}^2\rho\sigma^2+\lambda_1+\lambda_2-\lambda_3}$$

ANALYSIS ON THE SOLUTION

Analysis under symmetric information

If $\frac{k}{\lambda_1+\lambda_2-\lambda_3} \le \frac{1-k}{\lambda_3}$,it shows that the industry doesn't get the optimal profit but the research does under the best effort degree of the university. Obviously, in the double principal-agent only the second principal-agent namely the the U - R reach the optimization and the industry doesn't achieve the Pareto optimality,which conflicts with the single principal-agent conclusion. when $\frac{k}{\lambda_1+\lambda_2-\lambda_3} \ge \frac{1-k}{\lambda_3}$, $\frac{\partial Ev_1}{\partial a} < 0$,that is $v_1(\frac{k}{\lambda_1+\lambda_2-\lambda_3}) < v_2(\frac{1-k}{\lambda_3})$. At this time, the effort degree of the university beyond the industry's expectations,the revenue of the industry decreases which is the expected result of itself. The reason is that the investment of the industry I is related to the effort of the university a and the future earnings is uncertain. For the research, when observes $a < \frac{k}{\lambda_1+\lambda_2-\lambda_3}$, it means that the university has gotten the reservation utility and the cost is the least. So in the actual cooperation, the industry should combine the market research and the related data to accuratly estimate parameters λ_1, λ_2 and λ_3,make the scientific investment decision to save costs.

Analysis under symmetric information

$\gamma \ne 0$ means that in order to incentive the university, the research necessarily associates with the benefit of the university and let it undertake the income risk. At the same time, γ decreases along with σ and λ_2 , increases along with λ_3 .

It is to say, the more the value of ρ,the more the university tends to be risk-averse, the greater the uncertainty of future earnings,and the university is more worried about having tried without rewarded. Thus, its effort level reduces and so its earnings γ does. When λ_2 increases, the correlation of the research's income and effort cost rises,then the research will devote more energy to the cooperation, the earning ratio of the university reduces accordingly. So the scholars' earnings ratio of the scholars-researchers contract will reduce. When λ_3 increase, which is said that the industry increases the input including the investment and the supervision, leading to the probability increasing of the future earnings increase, the university's profit will also increase.

Compared with the game under the symmetrical information, $\frac{k}{\lambda_1^2\rho\sigma^2+\lambda_1+\lambda_2-\lambda_3}<\frac{k}{\lambda_1+\lambda_2-\lambda_3}$ is constantly established. It suggests that even if the university bares the income risk($\gamma \neq 0$),its effort degree will be lower than the one under the symmetric information, this is the so-called moral hazard. Accordingly, the industry reduces the investment, income uncertainty will increase. At this time,the research will reduce the supervision to the university to make the expected benefit maximal. Apparently,the three ones all get a ideal output and a stable cooperative state under a higher effort level of the university[11]. So the problem of the industry (the principal) is how to design incentive contract to tempt the university (the agent) to choose effort level what the industry and the research(the principal) expect.

STRATEGY ANALYSIS BASED ON PARAMETERS VARIATION

The above analysis shows that in the IUR synergy cooperation, when $\frac{k}{\lambda_1+\lambda_2-\lambda_3}\geq\frac{1-k}{\lambda_3}$,the IUR three ones all achieve the optimization under the symmetric information,improving the effort degree of the university is also the best way under the asymmetric information. As a result, parameters in the inequality are key points of the success of the IUR synergy.

The above inequality is established when increasing the incentive factor k and another parameters are invariant. It means to increase income distribution proportion of the research in the first principal-agent. The subjective initiative of the R&D personnel holds the key to the cooperation success. The higher the incentive factor, the greater the incentive intensity,the higher the research' effort level. But the industry's incentive cost increases accordingly. So the relationship among the revenue and cost of the industry and the incentive factor can be discussed to find the optimum point of the incentive contract.

The above inequality is established when reducing λ_1 and λ_2 and increasing λ_3. Reducing λ_1 and λ_2 means the effort cost coefficients of the university and the research decrease, which indicates the effort costs of the two decrease under the same effort degree. The university and the research can reduce the effort cost coefficient and boost profitability by bringing in new technology and focusing on moral culture construction. The IUR synergy itself is a spontaneous behavior of chasing profit, the corresponding responsibility and incentive mechanism can improve the connection between the investment and the profit. The local government departments can also take a series of measures of optimizing the allocation of scientific resources, driving the technological innovation, promoting the transformation of R&D achievements, to supportive the IUR synergy.

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