Acta Technica 62 (2017), No. 7A, 545–556

Research on economic risk control mechanism of large enterprises based on evolutionary game model

Yinxia Guo[1]

Abstract. Since knowledge loss risk is pervasive in inter-enterprise knowledge sharing, a method for research on economic risk control mechanism of large enterprises based on evolutionary game model is proposed in this Article to promote the effectiveness of research on economic risk control mechanism of large enterprises. For which, enterprise knowledge sharing action is divided into reciprocal action and opportunistic action, and dynamic game theory is used to analyze the dynamic evolution of both parties involved in knowledge sharing, to discuss the effect mechanism of risk attitude of parties in knowledge sharing on their knowledge sharing action, and the measures leading to their final choice of reciprocal action, then an examples is used to explain the conclusion. The results showed that: the risk attitude of parties in knowledge sharing have towards risks has impact on their knowledge sharing action; in order to choose suitable object for knowledge sharing, enterprises shall synthetically consider risk attitude of their own and of other enterprises; in order to promote knowledge sharing, both parties finally choose reciprocal action, and enterprises shall moderately increase the compensation claimed to the party of opportunistic action.

Key words. Evolutionary game, Large enterprises, Economic risk, Control mechanism.

1. Introduction

In the era of knowledge-based economy, the promotion of core competence in enterprises not only relies on integration and update of own core knowledge, but also on consolidation and absorption of external critical knowledge, which making inter-enterprise knowledge sharing become more and more common. In order to maximize own interest, enterprises might take some opportunistic actions such as knowledge imitating and embezzling, leaving other enterprises in risk of knowledge loss. Such problem has been attached with great importance in academic circles. Hamel pointed out that, enterprises consisting of alliance partners who aimed at internalizing enterprise knowledge are facing the risk of knowledge loss. Hagedoorn

[1]East Road sub-Branch,Tianjin Branch, Agriculture Bank of China,Tianjin, 300100, China

believed that, some enterprises participate in cooperation and innovation only for embezzling or abusing knowledge of other enterprises; while mQuintas et al thought that, when acquiring knowledge, enterprise might face with risk of core knowledge exposure caused by inter-enterprise knowledge transfer. Fitzgerald confirmed that, enterprise software development outsourcing contains the risk of knowledge theft.

The attitude of enterprises to risks is their attitude to an uncertain situation, that is to say, the degree of risk for enterprise participation. Enterprises always claim the party of opportunistic action for compensation and expose their opportunistic action; obviously, the risk attitude of an enterprise will affect their degree of supervision on other enterprises, and the probability of awareness and degree of punishment on opportunistic action of other enterprises, which will further affect the actions taken by other enterprises and finally affect the actions taken by the enterprise its own. Some scholars have paid attention to the significance of risk attitude by enterprises in a specific risk problem. Kim et al believe that, for the risk of unknown construction cost in bidding for projects, risk attitude of contractors affects their offering action and profitability. Du Jianguo et al found that, risk of attitude of supply chain members affects of their venture capital cost, and further affects the probability of suffering from the risk of supply chain disruption. Bao Xing et al confirmed that, risk attitude of managers affects the investment allocation on their ability for fast support and system-self capacity, which affects their total crash cost.

However, the significance of risk attitude of enterprises in inter-enterprise knowledge sharing with pervasive knowledge loss risk has not been valued. Therefore, in this Article, starting from the view of risk attitude of enterprises, dynamic game theory is used to study the effect mechanism of risk attitude of parties in knowledge sharing on their knowledge sharing action when such parties are facing with the risk of knowledge loss caused by the party of opportunistic action, to choose knowledge sharing objects for enterprises with different risk attitudes and provide reference for enterprises to promote sincere cooperation, and to prevent and control knowledge loss risk.

2. Creation of expected return matrix

2.1. Basic assumptions

From the view of actual venture capital, there are 3 moments for venture capitalists to sign a contract to gain returns. At Moment 1, venture entrepreneurs provide initial contract to venture capitalists, which, once accepted by venture capitalists, will be fed into capital I; if not, will not be fed into the same. Meanwhile, venture capitalists offer supervision and management services at cost of C_v; between Moment 1 and 2, venture enterprises have two possible natural operation status, ϕ and $\phi \in \{g, b\}$, in which ϕ_g is the good state of natural operation and ϕ_b is the poor one. At Moment 2, according to the project signal ϕ_g or ϕ_b observed, venture capitalists will negotiate on whether to re-allocate the control rights. At Moment 3, enterprises have returns, while both venture capitalists and venture entrepreneurs achieve returns. The structure of venture capital time sequence is shown in Figure 1.

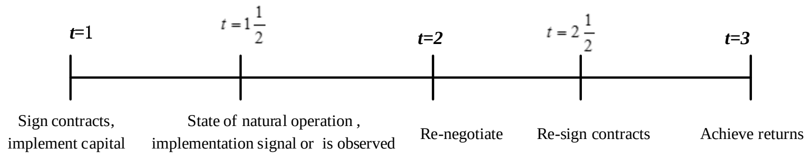

Fig. 1. Structure of venture capital time sequence

Combining with related Records and the structure of venture capital time sequence, based on research contents, following assumptions are made for allocation of control rights on venture enterprises by venture capitalists and venture entrepreneurs:

(1) There are 2 game participants with limited rationality in operation of venture enterprises—the group of venture capitalists and venture entrepreneurs, both of which repeat learning and gaming on choice of strategies.

(3) There are 3 ways for allocation of control rights on venture enterprises, unilateral control, camera control and joint control. In which unilateral control means the game player wholly owns control rights on venture enterprises; camera control means venture entrepreneurs own all control rights first, followed by re-allocation of the same as determined by the enterprise operating signal observed. At meanwhile, for choice of financial instruments, venture capitalists can choose convertible bonds, and not convert it if the enterprise natural operating signal is $\phi_b\,(\phi_b \in [0, 0.5])$ and still implement bond investment; if the enterprise natural operating signal is $\phi_g\,(\phi_g \in [0.5, 1])$, convert and implement equity investment. Joint control means both venture capitalists and venture entrepreneurs own proportional control rights first, and adjust such proportion according to development conditions of the enterprise, to control the enterprise jointly. Under method of unilateral control and joint control, venture capitalists implement equity investment both.

(3) Venture capitalists and venture entrepreneurs will gain control or not gain control for choosing strategies of active control on control rights on venture enterprises. Gain control is to own the control rights wholly or partly under unilateral control and joint control. While not gain control is to loss the control rights wholly or partly under camera control and unilateral control. Venture capitalists choosing strategy of gaining control account for u percent, while those choosing strategy of not gaining control account for $1 - u$ percent; venture entrepreneurs choosing strategy of gaining control account for θ percent, while those choosing strategy of not gaining control account for $1 - \theta$ percent.

2.2. Expected return matrix

We assume that a venture entrepreneur holds a new project requiring investment of K, its own funds is A, and $A < K$. A venture capitalist invests the fund I, and $I = A - K$; at meanwhile, venture capitalist offers supervision and management services at cost of C_v. The probability of project success is measured to be $P_H\,(P_H \in [0, 1])$ after statistical analysis, and the probability of project failure is $P_L\,(P_L \in [0, 1])$, the probability of project success is affected by the degree of venture entrepreneur efforts e positively, while probability of project failure is affected by the degree of venture entrepreneur efforts e negatively. The return is $\pi\,(\pi > 0)$ in case of project success, and 0 in case of failure. But, since venture capitalist is entitled to priority in claiming residual value of project in investment, in order to simplify the calculation, we assume in this Article that the residual value T in case of project failure is solely owned by venture capitalist, and $T < I$. In case of project success, the remaining claiming rights on project returns entitled to venture capitalist is $\omega, \omega \in [0, 1]$, so project returns available to be allocated by venture capitalist is $\omega\pi$, while by venture entrepreneur, it is $\omega, \omega \in [0, 1]$. If venture capitalist uses convertible bonds, before conversion and in case of project success, the project returns available to be allocated by venture capitalist is R, while by venture entrepreneur, it is $\pi - R$. Generally, venture capitalist implements equity investment to maximize its interest, and the return on equity obtained is expected to be higher than fixed income from bond investment, so $\omega\pi > R$ is considered. Whether to implement the convertible bonds is determined by the natural state of venture enterprises observed. Implementation is made if in good state and not if in poor state.

3. Evolutionary game model based on front-end comparison

3.1. Optimal performance in specific case

Figure 2 shows the several operating points selected, Table 1 gives economic risk control data on such operating points. Replace E^{wrx} in Formula (6) with each risk control indicator at front end, we assume that, as compared with risk control, the risk control indicators of large enterprises are ignored. Research in this Article aims to find economic risk controls that can obtain optimal performance of risk control energy in existing solutions. Graphical method is used and the calculation consists of two steps:

Step 1: Calculate case parameter Γ according to Formula (8), draw corresponding line of balance in given parameter and case.

Step 2: Start along lower left corner of the line of balance, until to the first risk control, which can provide minimum indicator parameter for specific risk control.

In the two sample cases mentioned above, illustrate how to choose optimal economic risks in risk control of large enterprises by examples, with corresponding data of Figure shown in Table 1. Firstly, add the line of balance corresponding to each case in Figure 2 (solid and dotted line).

Search for operation of economic risk control at (red) point 2.4 (nearest to point 2.4) starting from lower left side, obtain operating point[10]; while for Case 2, search for operation of economic risk control at (blue) point 780-950 (nearest to point 780-950) starting from lower left side, obtain operating point [14].

Table 1. Economic risk control case design in risk control

Reference Operating Points	Sensibility	Control Indicators	Control Rate	E^{wrx}
[15] Operating Point [15]	-87	45.5	50	-55.4
[7] Operating Point [7]	-50	65	40	-67.9
[8] Operating Point [8]	-72	52	100	-32.7
[10] Operating Point [10]	-56	7.4	100	-10.3
[11] Operating Point [11]	-53	19	50	-42.8
[12] Operating Point [12]	-65	10	100	-30.1
[14] Operating Point [14]	-45	0.161	12.5	-15.3

3.2. Optimal front end selection scheme

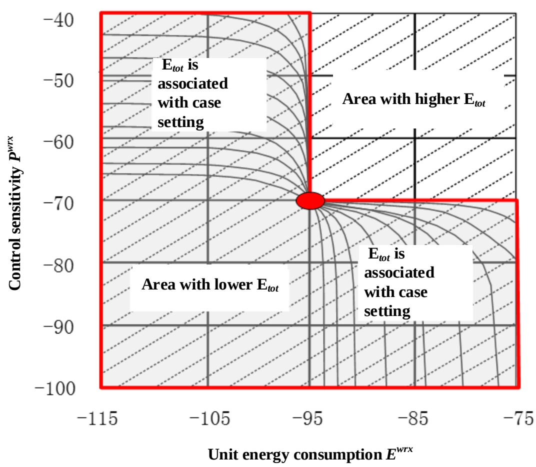

Fig. 2. Selection of single risk control operating point

The form of optimal indicator parameter operating line shown in Figure 1-2 is level and smooth, mainly because specific location for risk control of large enterprise and other information is not considered, making operating line impossible to have nodes for risk control, results are that risk control fails, or the selected group of nodes is not the optimal when moving operating line evenly for risk control.

For this purpose, in order to simplify optimal front end selecting method, the range ($(-\infty,\infty)$) of variation Γ is used to choose optimal economic risk control. Two cases are chosen for illustration: (1) selection of common single risk control operating point, as shown in Figure 2, (2) selection of multiple risk control operating points, as shown in Figure 3.

In selection of single risk control operating point shown in Figure 2, one operating point might be corresponding to optimal indicator parameters in all cases. Main points in illustration locate in the four areas created by a collection of horizontal curves (grey) by reference to location of risk control. Since as P_s^{wrx} and E^{wrx}

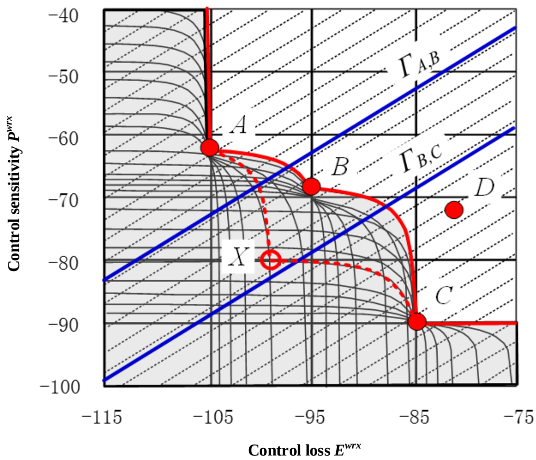

Fig. 3. Selection of multiple risk control operating point

increase, E_{tot} increases too. Therefore, any risk control designed under left lower quadrant has lower E_{tot} as compared with the reference risk control, while any risk control designed under right upper quadrant has higher E_{tot} as compared with the reference risk control, and the performance of risk control in other two quadrants is determined by different case settings.

In selection of multiple risk control operating point shown in Figure 3, for optimal risk control operating points, Point A is corresponding to $\Gamma > \Gamma_{A,B}$, Point B is corresponding to $\Gamma_{A,B} > \Gamma > \Gamma_{B,C}$, and Point C is corresponding to $\Gamma < \Gamma_{B,C}$, namely Point A, B and C is corresponding to optimal risk control operating points in three cases $\Gamma > \Gamma_{A,B}$, $\Gamma_{A,B} > \Gamma > \Gamma_{B,C}$ and $\Gamma < \Gamma_{B,C}$. In case boundary $\Gamma = \Gamma_{A,B}$ and $\Gamma = \Gamma_{B,C}$, for the former, Point A and B has the same indicator parameter performance; while for the latter, Point C and B has the same indicator parameter performance, Point D is not optimal for all cases.

In grey area, select new risk controlling point X, and assume its operating performance is superior to Point B, add it into optimal risk control collection and substitute Point B, which changes the case constants corresponding to risk control points A, X and C. Calculate Γs of case boundary according to economic risk control sensitivity and indicator parameters. For method selected in Figure 3, we assume $P^{wrx}_{s,A}$, $P^{wrx}_{s,B}$, E^{wrx}_{A} and E^{wrx}_{B} represent unit sensitivity and indicator parameter (/bit) of Point A and Point B respectively, and identify case boundary constant in combining with Formula (1):

$$\Gamma_{A,B} = -\frac{P^{wrx}_{s,A} - P^{wrx}_{s,B}}{E^{wrx}_{A} - E^{wrx}_{B}} \,. \tag{1}$$

Formula (9) defines the case constant Point A and B with same predicted values of risk control energy, which is positive real number. That means if the correlation between sensitivity and indicator parameter by size differs, it is impossible that the two economic risk controls have the same performance, which is corresponding to the performance of features in lower left and upper right quadrant as shown in Figure

3.

Apply mechanisms above into two cases shown in Table 1 respectively: point 2.4 and 780-950, results of selection are shown in Figure 4a-4b.

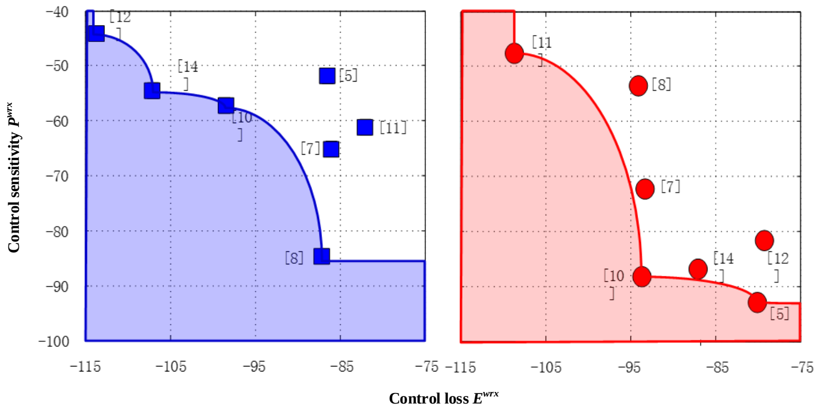

Fig. 4. Front end of optimal implementation simulation

As shown in Figure 4, in the two sub diagrams, all economic risk controls designed on solid lines are in collection of optimal risk control. In which, the white area is not optimal risk control designs in the two cases. In the text below, select optimal risk control operating points, for risk control point B in Figure 3, the scope is between $\Gamma_{A,B}$ and $\Gamma_{B,C}$. For multiple cases, the greater the value in this scope is, the better the performance is. Calculate risk control boundary constant with best performance under two cases with Formula (9), as shown in Figure 4. The calculated value in this scope is shown in Table 2-3.

Table 2. Scope of 780-950 case constant

Reference Operating Point	Scope of Case Parameters
Operating Point [12]	Minimum E^{wrx}
Operating Point [14]	33.5
Operating Point [10]	23.4
Operating Point [8]	Minimum P_s^{wrx}

Table 3. Scope of 2.4 case constant

Reference Operating Point	Scope of Case Parameters
Operating Point [11]	Minimum E^{wrx}
Operating Point [10]	4.3
Operating Point [5]	Minimum P_s^{wrx}

For extreme cases with extremely large or small constant, the above results are the optimal. Corresponding to 780-950 case, operating point [27] is the optimal, while to case, operating point [20]is the optimal.

3.3. Algorithm calculation steps

Algorithm steps for risk control node selection mechanism based on front end priority as mentioned above are shown in pseudocode.

Pseudocode: Comparison of Risk Control Mechanism with Front End Priority

Input: Worst control loss $L_{p,\max}$, network size N, control interval $(1/\lambda)$, control delay demand average value D^{req}, WB risk control indicator W, control efficiency factor η, and WB data length Z_{wb}.

Output: Simulation front end for risk control of large enterprises

1. for i=1: N do

2. $W = (1/\lambda)/2KZ_{wb}T_b(\ 2)$

3. $K = (1/\lambda)/2D^{req}(\ 3)$

4 . $P^{tx} = P_s^{wrx} L_{p,\max}/\eta(\ 4)$

5. $E^{wrx} = P^{wrx}T_b(\ 5)$

6. $E_{tot} = \frac{D^{req}L_{p,\max}}{\eta Z_{wb}} P_s^{wrx} + N\frac{1/\lambda}{2D^{req}} E^{wrx}(\ 6)$

7. endfor

8. Use the parameter values to obtain total control loss/risk control horizontal curve in Figure 1

9. $\Gamma = N + \eta + Z_{wb} + (1/\lambda) - 2D^{req} - 3 - L_{p,\max}[dB](\ 8)$

$\Gamma = N + \eta + Z_{wb} + (1/\lambda) - 2D^{req} - 3 - L_{p,\max}[dB]$ (formula 8)

10. $P_s^{wrx} = E^{wrx} + \Gamma[dB]$

$P_s^{wrx} = E^{wrx} + \Gamma[dB]$ (formula 7, for calculation of line of balance)

11. Draw line of balance, search from left lower side to right upper side along the line of balance

12. Collect the first risk control operating points on all lines of balance

13. Select optimal risk control operating points for different boundary area

14. Control all optimal risk control operating points to obtain the optimal simulation front end

The network size involved in above algorithms is N, we can see from pseudocode steps that, during above process, only single cycle execution structure is contained, thus the calculation complexity is $\mathcal{O}(N)$.

4. Experimental analysis

We assume knowledge sharing happens between Enterprise A and B. Excess return v by the party of opportunistic action is RMB 500 thousand, who has to pay RMB 800 thousand to the party of reciprocal as compensation, and the loss of reputation f caused by exposure of opportunistic action is RMB 1.2 million, while $\theta_k\,(k = 1, 2)$ of party of risk preference, of risk neutral and of risk aversion is in $\left(0, \frac{1}{4}\right)$, $\left(\frac{1}{4}, \frac{5}{8}\right)$, and $\left(\frac{5}{8}, 1\right)$ respectively.

For Case I to VI, randomly generate 30 groups of risk attitude factors of Enterprise A and B in each case, and use MATLAB for dynamic game simulation. The results showed that, 60 final nash equilibriums of Case I and VI is \ $x^* = 1$, $y^* = 1$; 60 final nash equilibriums of Case II and V is $x^* = 0$, $y^* = 0$. And the 30 final nash equilibriums of Case III might be $x^* = 0$, $y^* = 0$ or $x^* = 1$, $y^* = 1$; in addition to the two counterexamples, in 28 cases of Case III, when risk attitude of Enterprise A and B get close to each other, the final nash equilibrium is more possibly to be $y^* = 1$; no final nash equilibrium in 30 cases of Case VI. Results of 1 simulation selected randomly from Case VI only are shown in Figure 5; results of simulation from Case II are shown in Figure 6 and the results of 4 simulations from Case III are shown in Figure 7.

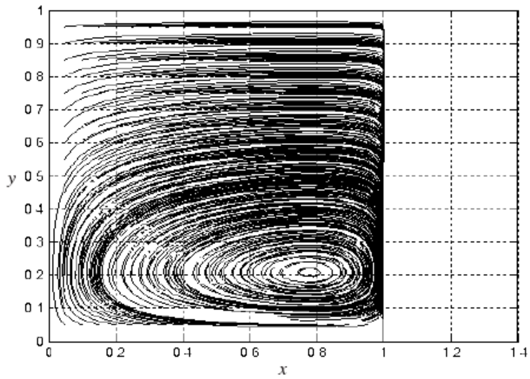

Fig. 5. System simulation of case VI

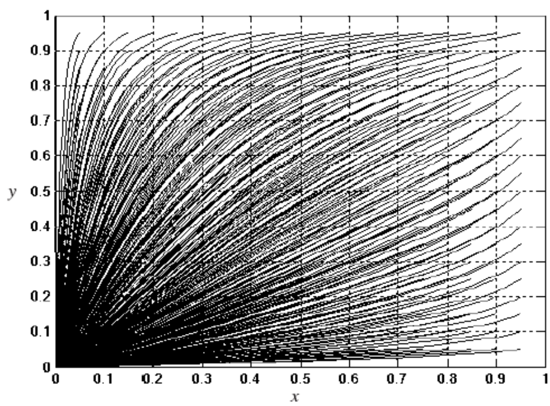

Fig. 6. System simulation of case II

Figure 5 reflects that, if the parties are in risk aversion and preference respectively, they finally have no stable knowledge sharing action. Figure 6 shows that, if there is no party of risk preference but of risk aversion, both parties finally choose reciprocal action; if there is no party of risk aversion but of risk preference, both parties finally

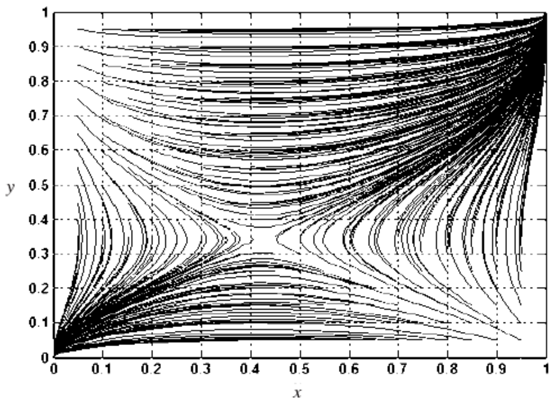

Fig. 7. System simulation of case III

choose opportunistic action. And Figure 7 confirms that, if both parties are in risk neutral, they might finally choose opportunistic action, or reciprocal action, and if the risk attitude of both parties approaches to each other, the probability of choosing reciprocal action is higher.

5. Research conclusions

(1) Risk attitude by both parties in knowledge sharing affects their knowledge sharing action: if there is no party of risk preference but of risk aversion, both parties finally choose reciprocal action; if there is no party of risk aversion but of risk preference, both parties finally choose opportunistic action; if both parties are in risk neutral, they might finally choose opportunistic action, or reciprocal action, and if the risk attitude of both parties approaches to each other, the probability of choosing reciprocal action is higher; if the parties are in risk aversion and preference respectively, they finally have no stable knowledge sharing action.

(2) In order to make both parties in knowledge sharing finally choose reciprocal action, enterprises shall choose suitable knowledge sharing objects according to risk attitude of their own and of other enterprises: the party of risk aversion shall choose the party of non- risk preference; the party of risk neutral shall choose the party of risk aversion, and the party of risk neutral approaching to its own risk attitude if there is no party of risk aversion; and the party of risk preference shall not choose any enterprise.

(3) In order to promote both parties in knowledge sharing finally choose reciprocal action, enterprises shall moderately increase the compensation claimed to the party of opportunistic action, meanwhile, if there is no original party of risk preference, but original party of risk aversion, both parties shall finally choose reciprocal action; in remaining cases, the probability of choosing reciprocal action by both parties increases.

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Received May 7, 2017