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Collaborative Innovation Contracting in Double Moral Hazard

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ABSTRACT
Under the background of innovation driven strategy in China, collaborative innovation can accelerate the speed of enterprise innovation and improve enterprise innovation performance. The key to collaborative innovation is effective contract governance. Due to the knowledge stickiness in collaborative innovation, the level of effort input of both sides cannot be confirmed and supervised without cost, and that results in double moral hazard. Based on the principal-agent model, this paper analyses the contract design of enterprise collaborative innovation under the condition of double moral hazard from two aspects of residual incentive payment and fixed payment. The conclusion shows that the residual incentive payment of the contract is negatively correlated with the knowledge stickiness of the cooperative innovation initiator enterprise, and the fixed payment of the contract is positively correlated with the knowledge stickiness of the cooperative innovation initiator enterprise.

Keywords: *collaborative innovation, knowledge stickiness, double moral hazard, contract governance*

1. INTRODUCTION AND REVIEW

Enterprise collaborative innovation can accelerate the speed of enterprise innovation and improve the performance of enterprise innovation through the resource integration and in-depth cooperation among them, so that enterprises can obtain the synergy benefits beyond their own ability. However, it is not easy to realize the effective collaborative innovation of multi-agent. The main reason is not the technical factors of collaborative innovation, but the innovation of management and coordination mechanism. Because enterprise collaborative innovation needs all participants to work together to create value, cooperation is a key consideration in enterprise collaborative innovation. At the same time, the essence of enterprise collaborative innovation is the process of knowledge sharing, transfer, processing and recreation among the collaborative agents. The existence of knowledge stickiness has an important impact on the performance of collaborative innovation. Moreover, due to the uncertainty of resource demand in the process of collaborative innovation, it will be very difficult to determine the effort input of each participant in advance. They will face a lot of problems of task redistribution and contract renegotiation in the process of implementing the cooperative contract. The collaborative innovation contract will be a typical incomplete contract. Therefore, it is an important research issue to consider the cooperation characteristics of the collaborative innovation agents and the incomplete contract design in the case of knowledge stickiness.

Xue and Field (2008) [1] studied the influence of knowledge stickiness on contract design in knowledge intensive service consulting industry. The conclusion shows that knowledge stickiness between consulting service providers and customers leads to the decline of cooperation efficiency, and the party with high cost of knowledge stickiness should have the residual control of incomplete contract. However, the hypothesis that the level of effort of the two partners is replaced by each other is controversial. Roels and Karmarkar (2010) [2] studied the choice of contract under the assumption that the efforts of both sides are complement each other. The conclusion shows that in the case of double moral hazard, the cooperation contract will be a linear incentive contract based on output performance, and the proportion of residual incentive is positively related to the relative importance of both sides. However, the cooperation contract in the case of double moral hazard includes two parts: fixed payment and residual incentive distribution. The former does not affect the choice of effort input level of both sides, but it is an indispensable part to ensure the implementation of cooperation. Roels and Karmarkar's research failed to further analyze the fixed payment decision of contracts. Bin Dan et al. (2010) [3] studied the outsourcing contract design in R&D field under the condition of double moral hazard, and discussed both fixed payment and residual incentive payment, but they failed to point out the relationship between the optimal fixed payment and the relative importance of both parties. Applied to the field of collaborative innovation, Ying-yuan Guo et al. (2018) [4] analyzed the theoretical mechanism of knowledge stickiness in R&D teams, and pointed out that knowledge retention caused by knowledge stickiness affects the performance of R&D teams. Bi-yi Yi and Li Zeng (2020) [5] studied the knowledge coupling collaborative innovation model. However, they both ignore the adaption problem on the contract selection and structure of collaborative innovation.

Based on this, this paper takes the contract design of enterprise collaborative innovation under the situation of double moral hazard as the research object, analyzes the value output of collaborative innovation, emphasizes cooperative participation, highlights the influence of knowledge management, comprehensively considers the decision-making factors of fixed payment and residual incentive payment, and provides further theoretical reference for enterprise collaborative innovation contract governance.

2. MODEL BUILDING

2.1. Model Hypothesis

2.1.1. Model Input

The input of the model is the knowledge effort input level of the collaborative innovation enterprise. The input level of the collaborative innovation initiator enterprise (Party A) is x, and the input level of the collaborative innovation responder enterprise (Party B) is y. Under the assumption that both parties are risk neutral, the cost function of intellectual effort input of the initiator (Party A) is $\frac{1}{2}x^2$, and that of the responder (Party B) is $\frac{1}{2}y^2$.

2.1.2. Model Output

For enterprises or organizations to carry out collaborative innovation activities, the participants are complementary to each other, so the production function emphasizing team spirit is the output of the model, $V(x,y)$, $V(x,y)=x^{\alpha}y^{1-\alpha}+\varepsilon$, which is continuously differentiable. α （$0<\alpha<1$）is the relative importance of the knowledge effort input of Party A, which is used to explain the dependence of collaborative innovation output on Party A's enterprise knowledge. In turn, the relative importance of the knowledge effort input of Party B is 1-α. ε is a random variable which represents the random interference in the collaborative innovation output.

The expected value of collaborative innovation is satisfied as follows:

(1) $V(x,0)=V(0,y)=0$

(2) $\lim_{y\to\infty}\partial(x,y)/\partial x=\lim_{x\to\infty}\partial(x,y)/\partial y=\infty$

2.1.3. Unverifiability

For collaborative innovation activities, the output is mainly based on the knowledge input of both sides. The existence of knowledge stickiness makes the effort level of both sides can be observed, but cannot be confirmed freely, so it will produce double moral hazard.

2.1.4. Ttransfer Payment

The model assumes that the output of collaborative innovation has two functions, one is to guarantee the basic fixed income of both parties participating in collaborative innovation, the other is the incentive income shared by both parties according to a certain proportion.

$$V_x=S_x+\rho(V-S_x-S_y)=(1-\rho)S_x+\rho(V-S_y)$$
$$V_y=S_y+(1-\rho)(V-S_x-S_y)=[\rho S_y-(1-\rho)S_x]+(1-\rho)V$$

V_x and V_y are respectively the vested income of enterprise A and enterprise B, S_x and S_y are respectively the fixed income of A and B, ρ and $(1-\rho)$ are respectively the distribution proportion of cooperative output, and 0<ρ<1.

2.2. Model Formation

Therefore, if the primary distribution of output is completely owned by the collaborative innovation initiator (Party A), Party A needs to make the secondary transfer payment to the collaborative innovation responder (Party B), which is the fixed payment part. From the perspective of the principal (Party A), the problem of optimal control right arrangement can be expressed as follows:

$$\max_{x,\,y\geq 0}\pi=\rho x^{\alpha}y^{1-\alpha}-\frac{1}{2}x^2-M \tag{1}$$

St. $$y\in\arg\max_{y}\left[M+(1-\rho)x^{\alpha}y^{1-\alpha}-\frac{1}{2}y^2\right] \tag{2}$$

$$M+(1-\rho)x^{\alpha}y^{1-\alpha}-\frac{1}{2}y^2\geq U \tag{3}$$

Equation (1) is the objective function of maximizing the expected utility of Party A in collaborative innovation, while equation (2) is the incentive compatibility constraint and equation (3) is the participation constraint of Party B in collaborative innovation.

$$x = (\alpha\rho)^{\frac{1}{2-\alpha}} y^{\frac{1-\alpha}{2-\alpha}} \tag{4}$$

$$y = [(1-\rho)(1-\alpha)]^{\frac{1}{1+\alpha}} x^{\frac{\alpha}{1+\alpha}} \tag{5}$$

In addition, because the participation constraints of Party B do not generate incentives, under the optimal situation, the fees paid by Party A to Party B will not be greater than the retention utility of Party B. the participation constraints of Party B can be written as follows:

$$M = U - (1-\rho)x^{\alpha} y^{1-\alpha} + \frac{1}{2}y^2 \tag{6}$$

Substituting (6) into (1), we get:

$$\max_{x,\, y\ge 0} \pi = x^{\alpha} y^{1-\alpha} - \frac{1}{2}x^2 - \frac{1}{2}y^2 - U \tag{7}$$

The model is formed.

3. MODEL ANALYSIS

3.1. Model Solving

By solving equations (4) and (5), we can get the following results:

$$x^{DM} = (\alpha\rho)^{\frac{1+\alpha}{2}} [(1-\alpha)(1-\rho)]^{\frac{1-\alpha}{2}} \tag{8}$$

$$y^{DM} = (\alpha\rho)^{\frac{\alpha}{2}} [(1-\alpha)(1-\rho)]^{\frac{2-\alpha}{2}} \tag{9}$$

By substituting (8) and (9) into (7), the maximum expected output function of Party A in collaborative innovation is obtained：

$$\pi^{DM} = (\alpha\rho)^{\alpha}[(1-\alpha)(1-\rho)]^{1-\alpha}\left(1 - \frac{\alpha\rho}{2} - \frac{(1-\alpha)(1-\rho)}{2}\right) - U \tag{10}$$

The optimal arrangement of residual control rights can be obtained：

$$\rho^* \in \left\{\rho \;\middle|\; (2\alpha-1)\rho^2 - (\alpha^2+\alpha)\rho + \frac{1}{2}(\alpha^2+\alpha) = 0 \right\} \tag{11}$$

By solving equation (10), multiple roots can be got:

$$\rho = \frac{(\alpha+\alpha^2) \pm \sqrt{(\alpha+\alpha^2)(\alpha-2)(\alpha-1)}}{2(2\alpha-1)}$$

Because $\rho = \frac{(\alpha+\alpha^2) + \sqrt{(\alpha+\alpha^2)(\alpha-2)(\alpha-1)}}{2(2\alpha-1)}$ is less than zero, it is an invalid solution. Therefore, the optimal arrangement of residual control rights is:

$$\rho^* = \frac{(\alpha+\alpha^2) - \sqrt{(\alpha+\alpha^2)(\alpha-2)(\alpha-1)}}{2(2\alpha-1)} \tag{12}$$

The optimal incentive coefficient of Party B in collaborative innovation is:

$$1-\rho^* = \frac{-(\alpha-2)(\alpha-1) + \sqrt{(\alpha+\alpha^2)(\alpha-2)(\alpha-1)}}{2(2\alpha-1)} \tag{13}$$

Substituting (8), (9) and (13) into (6), the fixed payment is as follows:

$$M^{DM} = U - \frac{(\alpha\rho)^{\alpha}[(1-\alpha)(1-\rho)]^{1-\alpha}(1-\rho)(1+\alpha)}{2} \tag{14}$$

Therefore, the transfer payment function of Party A to Party B is:

$$t = M^{DM} + (1-\rho^*)V^{DM} \tag{15}$$

3.2. Parameter Analysis

3.2.1. Influence on Residual Incentive Payment by Knowledge Stickiness

The derivation of equation (13) is:

$$\frac{\partial(1-\rho^*)}{\partial\alpha} = -2\left[(2\alpha^2 - 2\alpha - 1) - \frac{2\alpha^4 - 4\alpha^3 + 3\alpha^2 - \alpha - 1}{\sqrt{(\alpha+\alpha^2)(\alpha-2)(\alpha-1)}}\right] \tag{16}$$

Therefore, we have the following deductions:

Deduction 1: in the case of double moral hazard, the optimal residual incentive payment of Party A to Party B is negatively correlated with the knowledge stickiness of Party A.

3.2.2. Influence on Fixed Payment by Knowledge Stickiness

$M^{DM} < U$ can be seen from equation (14). Because fixed payment is a positive correlation function of residual incentive ρ. And considering $\frac{\partial(1-\rho^*)}{\partial\alpha} < 0$, $\frac{\partial\rho^*}{\partial\alpha} > 0$ is established. So, there is a conclusion of $\frac{\partial M^{DM}}{\partial\alpha} > 0$, which leads to deduction 2.

Deduction 2: the optimal fixed payment obtained by Party B will be less than its reserved utility, and it is positively related to Party A’s knowledge stickiness.

3.2.3. Situation of Equivalent Knowledge Stickiness of Both Parties

When α =1/2, we can get ρ^* =1/2 by equation (11). So, there is deduction 3.

Deduction 3: when the dependence of collaborative innovation on both sides' knowledge input is equivalent, both sides will share the residual incentive equally in the case of double moral hazard.

4. CONCLUSION AND PROSPECT

In the process of collaborative innovation, due to the knowledge stickiness of participants, knowledge input or the effort behavior of both parties cannot be confirmed and supervised without cost, so there is the problem of double moral hazard in team cooperation. From the perspective of collaborative innovation incentive, this paper focuses on the impact of knowledge investment on the design of collaborative innovation contract governance mechanism in the case of double moral hazard, and comprehensively considers the decision-making factors of fixed payment and residual incentive payment. The results show that, in the case of double moral hazard, the stronger the dependence of collaborative innovation project on the knowledge input of the sponsor (Party A), the greater the knowledge stickiness of Party A, the higher the fixed payment part of the contract. After Party B obtains a large fixed fee similar to the patent royalty at the start of the project, there is a weak correlation between the revenue of collaborative innovation of subsequent projects and Party B. The incentive intensity of Party B is weakened, and Party A plays a relatively leading role in the implementation process of collaborative innovation project. On the contrary, if the intellectual investment of the responder (Party B) enterprise has a greater impact on collaborative innovation activities, the greater the knowledge stickiness of Party B, the stronger the incentive intensity of the transfer payment contract, the lower the threshold of Party B's participation (the fixed payment part is reduced), and Party B is more active in the process of project implementation to pursue greater residual incentives. It will also face greater risk of innovation failure, which is the mainstream of many R&D outsourcing contracts. In the case that collaborative innovation relies on the knowledge input of both parties equally, "partnership" contract will be the best choice for participating enterprises. At this time, both enterprises will share risks and profits, and will spare no effort to invest in the innovation process of the project regardless of risks, which is generally adopted in the initial stage of the project.

This paper assume that all participants are risk neutral and it don't consider the specific verification cost or verification efficiency of the level of knowledge input of participants. Generally speaking, the relative importance of the participants, the supervision efficiency of the effort level of the participants, the risk aversion degree of the participants and other factors will interact with the arrangement of the residual control right of the contract. Therefore, it will be our further research direction to consider the impact of input level of knowledge stickiness, verification cost and supervision efficiency, as well as risk aversion degree of collaborative innovation participants on collaborative innovation contract design.

AUTHORS' CONTRIBUTIONS

This research provides a more comprehensive theoretical reference for the design of collaborative innovation contract governance mechanism.

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