Research on Incentive Mechanism of Knowledge Contribution of Enterprise Staff Based on Multi-task Principal-agent Theory

Le Cheng-yi [1], Duan Nuan-nuan[1]

1 *School of Economic and Management*
East China Jiaotong University
Nanchang, Jiangxi, China

***Abstract* — At present, how to motivate staff to enhance their performance according to their different knowledge contribution behavior is a crucial issue in the research and practice of enterprise knowledge management. A new multi-task principal agent model is established to improve the knowledge contribution and knowledge competitiveness. In this paper, staff's knowledge contribution behavior in knowledge creation and knowledge participation is described to explain the multi-task principal-agent relationship between enterprise and staff. Then, the multi-task principal agent model of knowledge contribution is built and analyzed. Finally, some incentive measures are proposed for enterprises to prompt knowledge contribution of creation and participation. The results show that staff's knowledge creation behavior and positive participation behavior will promote each other. Enterprise should set up respective target levels of both knowledge creation contribution and knowledge participation contribution, and make them irreplaceable. The research demonstrates that the proposed model is effective for the study of incentive mechanism of knowledge contribution.**

Keywords - Knowledge contribution behavior, Multi-task Principal-agent, Knowledge creation contribution, Knowledge participation contribution, Incentive measures

I. INTRODUCTION

Employees, both the creators and users of knowledge, are enterprises' key resources and sources of knowledge. Enterprise knowledge base's ordering construction requires staff's collective participation and wisdom [1]. However, employees worry that their knowledge dominance may be jeopardized, thus they have no willingness to share useful knowledge with others [2]. It is worth to mention that, How to motivate staff to contribute knowledge has been a crucial issue in the research and practice of enterprise knowledge management. Studies have shown that the largest challenge to knowledge management is whether individuals have intentions to propagate and share useful knowledge [3]. And enterprise always will take some incentive measures according their knowledge contribution behaviors, to encourage employees to contribute their knowledge. Besides, knowledge participation behavior and knowledge creation behavior have different effects on the knowledge contribution in enterprise [4]. Based on the multi-task principal-agent theory, when the agent is engaged in a number of tasks, incentives of one of the task is not only influenced by this task, but also influenced by other tasks [5]. That is very important to consider the differences of knowledge contribution behaviors, and make different incentive measures of knowledge creation task and knowledge participation task. Therefore, the paper constructs and analyzes the multi-task principal agent model of knowledge contribution, so that enterprise can propose some efficient measures to encourage staff to create and share knowledge.

II. LITERATURE REVIEW

The principal-agent theory has widely application in the research of information asymmetry and incentive issues, and it can be used to study the incentive problems of knowledge sharing in enterprise. Many scholars have applied the principal-agent theory in the economics analysis of incentive mechanism of knowledge sharing among employees. For instance, Wei Hong-mei et al. (2009) established knowledge sharing incentive mechanism model, dividing company clients into either risk neutral or risk aversion, and discussed their respective optimal incentive contract. Fan Bin et al. (2009) studied enterprises' internal knowledge sharing mechanism under the condition of incomplete information. Zhang Peng et al. (2011) analyzed the incentive mechanism of crowdsourcing based on the principal-agent theory, and discussed how the enterprise should design the incentive mechanism. Yu Lin et al. (2011) put forward compensation strategy for tacit knowledge sharing behavior, helping achieve the flow, transformation, sharing and innovation of tacit knowledge. Liu Min-Shi (2012) explored the relationship among knowledge incentive mechanisms, knowledge psychological ownership, and individual knowledge creation behavior. Gong Lin (2014) proposed an incentive mechanism to realize knowledge sharing for improving the effect of the inter-organizational knowledge sharing in cooperative R&D. Besides, some researches focused on the studies of knowledge contribution in online communities. Jin Jia-hua et al. (2015) explored why users continuously contribute knowledge to online social Q&A communities. Cheng Zhi-chao and Guo Tian-chao (2015) brought social interaction tie and membership esteem

together as the mediating variables between knowledge contribution and social identity to construct an inductive route model, it showed that self-identity can form through an inductive route. Ye Hua-Jonathan et al. (2015) showed that perceived community support and perceived leader support positively affect users' knowledge contribution [6-8].

Although many scholars have studied the knowledge sharing problem based on principal agent theory, but most of the principal-agent models of knowledge sharing have not considered the discrepancies between different knowledge behaviors of enterprise staff, and also have neglected the interaction between different knowledge contribution behaviors and tasks. Thus the multi-task principal agent model of the knowledge contribution is proposed to improve knowledge sharing in enterprise [9, 10].

The remainder of this paper is organized as follows: Section 3 describes the principal-agent relationship between enterprise and staff, and the behavior of knowledge creation and participation. Section 4 gives the methodology of multi-task principal-agent model for knowledge contribution. Section 5 presents the results, analysis, and discussion of the model. Section 6 summarizes the conclusions [11].

III. DESCRIPTION OF ENTERPRISE KNOWLEDGE CONTRIBUTION RELATIONSHIP AND BEHAVIOR

A. Principal-agent relationship of enterprise knowledge contribution

There is a principal-agent relationship of knowledge contribution between the enterprise manager and staff. Enterprise manager, as the principal, knows that knowledge comes from the minds of all staff, and encourages the staff to contribute their knowledge. As the owner of the knowledge, the staff is the agent of knowledge contributing. When enterprise manager requests the staff to contribute their knowledge, the principal-agent relationship of the knowledge contribution of the enterprise is established, as shown in Figure 1. In addition, there is information asymmetry between the manager and the staff; the staff has information superiority, but enterprise manager doesn't [12].

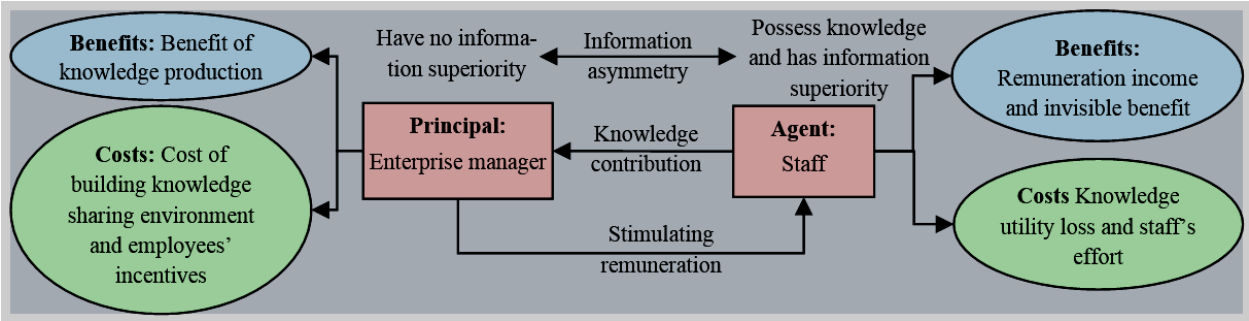

Figure 1. Principal-agent relationship of knowledge contribution between enterprise manager and staff.

The staff doesn't contribute their knowledge without stimulating remuneration. Then enterprise manager provide some incentive to encourage the staff to contribute their own knowledge, aiming to maximize benefits of the enterprise. The staff considers that knowledge contribution will take many time and efforts, and will also lose their ownership of the knowledge. By weighing the benefits and costs of knowledge contribution, the staff determines the level of knowledge contribution [13, 14].

B. Behaviors of knowledge creation and knowledge participation contribution

Knowledge contribution behaviors of the staff can be divided into two parts: direct knowledge contribution and indirect knowledge contribution. (1) Direct knowledge contribution: the staff produces and creates new knowledge to make contributions, such as new products, new design. (2) Indirect knowledge contribution: the staff takes an active part in knowledge sharing activities, e.g. knowledge reading, knowledge recommendation, knowledge transfer, knowledge evaluation, knowledge sharing and exchanging. Both of them are helpful for the positive knowledge sharing environment. The former which requires much energy and time on knowledge creation and innovation, is called knowledge creation contribution behavior. The latter which needs staff to active participate in using, sharing and evaluating of enterprise knowledge, is called knowledge participation contribution behavior, as shown in figure 2.

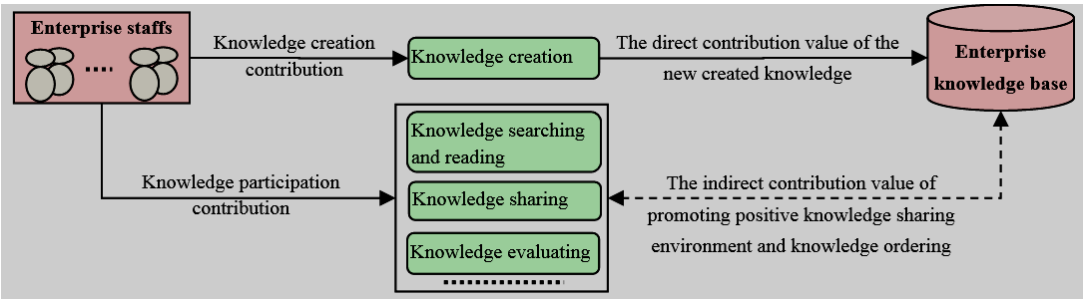

Figure.2 Behavior of knowledge creation and participation contribution.

IV. METHODOLOGY

A. Assumption and function description

The paper make some following assumptions: Principal (enterprise manager, P)，Agent (employee, A). They are all independent person who aiming to maximize their own interests. The risk attitude of the principal is risk neutral and the agent is risk aversion. There is information asymmetry between the principal and the agent, that is to say, the principal cannot fully understand the level of the efforts of knowledge contribution of the agent.

Agent has two knowledge contributing tasks: knowledge creation contribution and knowledge participation contribution. $a_i (a_i \geq 1,\ i = 1,2)$ is used to express the efforts of the agent, and $a_i = 1$ denotes that the level of staff effort is 0; a_1 means the efforts that agent spent on knowledge creation, a_2 represents the agent's efforts of knowledge participation.

(1) Knowledge production function

According to the knowledge production function model proposed by (Griliches 1979), the paper supposes that the agent's knowledge contribution output function is a linear function about agent's effort level of knowledge contribution, so the knowledge contribution output function can be expressed as: $\pi_i = r_i a_i + \varepsilon_i$. r_i is the coefficient of the agent's effort to output; ε_i represents output random factors which obeys normal distribution, setting its mean to be 0 and covariance to be Σ, $i = 1,2$ denotes the different results from different degrees of efforts of knowledge creation and knowledge participation.

$\pi_1 = r_1 a_1 + \varepsilon_1$, $\pi_2 = r_2 a_2 + \varepsilon_2$; $\varepsilon_1, \varepsilon_2$ are respectively independent, and they subject to normal distribution: $N = (0, \sigma_1^2)$. For simplicity, supposing if $r(a_1, a_2) = (a_1, a_2)$, so the output function is: $\pi_i = a_i + \varepsilon_i$; π_i as the expected revenue of the principal, is a strictly increasing convex function ($\frac{\partial \pi}{\partial a_i} > 0, \frac{\partial^2 \pi}{\partial a_i^2} \leq 0$).

(2) Cost function of knowledge contributing

The agent spends a certain amount of time and effort on knowledge creating, sorting and sharing. So the paper assumes the effort cost function of the staff is $C = \frac{1}{2} c a^2$, $C(a_1, a_2)$ denotes the effort cost that agent spends on knowledge creation and knowledge participation, and it is a strictly increasing convex function:

$$C_i = \frac{\partial C}{\partial a_i} > 0, c_{ii} = \frac{\partial^2 C}{\partial a_i^2} \geq 0, c_{ij} = c_{ji}$$

When $c_{ij} = 0$, it says that knowledge creation contribution and knowledge participation contribution of agent are independent of each other, that is, a change of the effort cost of one task will not affect the effort cost of another task.

When $c_{ij} < 0, i \neq j$, it shows that the two tasks of the agent are mutually complementary, namely, the reduction of the effort cost of one task will cause the increase of the effort marginal cost of another task.

When $c_{ij} > 0, i \neq j$, it represents that two contribution tasks of the agent can be replaced, in other words, a rise in one task's effort cost will lead to an increase of another task's marginal effort cost.

(3) Incentive contract function

Since the principal cannot directly observe agent's effort level (a_i), but he can find agent's knowledge contribution output (π_i). Therefore, the incentive contract function is expressed as: $s(\pi) = \alpha + \beta_i \pi_i$; α is the fixed remuneration provided by the principal, β_i as the incentive intensity of knowledge contribution.

B. Multi-task principal-agent model of knowledge contribution

According to the above assumptions, the revenue of the principal depends on the effort the agent. The revenue can be got if subtracting the knowledge contribution contract payment from agent's revenue expectation of knowledge output; the principal's expected revenue is: $E(w_p) = E(\pi - s(\pi)) = \pi(a_1, a_2) - \alpha - \beta^T(a_1, a_2)$. And the agent's expected revenue is: $E(w_a) = E(s(\pi) - C) = \alpha + \beta^T(a_1, a_2) - C(a_1, a_2)$.

Because the agent is risk averse, the risk cost of the external influence must be considered. Thus, the equivalence income of the agent is: $F_a = E[s(\pi) - C - \frac{1}{2}\rho\beta^2\sigma^2] = \alpha + \beta^T(a_1, a_2) - C(a_1, a_2) - \frac{1}{2}\rho\beta^T\Sigma\beta$, with ρ being absolute risk aversion measure, Σ being the covariance matrix of the random factor (ε_i), and $\frac{1}{2}\rho\beta^T\Sigma\beta$ being the risk cost of the external influence of the agent.

The principal expects the agent to work hard for his own profit maximization, and the agent is also seeking for his own interests. So the incentive compatibility constraint (IC) is required, that is:

$$\max_a f_a = \alpha + \beta^T(a_1, a_2) - C(a_1, a_2) - \frac{1}{2}\rho\beta^T\Sigma\beta$$

The agents are willing to participate in knowledge contribution, only if the profit is not less than the retained revenue. Therefore, the agent's participation constraint (IR) is necessary,

$$F_a = \alpha + \beta^T(a_1, a_2) - C(a_1, a_2) - \frac{1}{2}\rho\beta^T\Sigma\beta \geq \omega$$

ω is the agent's retained revenue.

The problem that the principal faces is how to set β^T, so that his income (F_p) is the largest, as the function:

$$\max_{\beta^T}\max_{\beta^T} F_p = \pi(a_1, a_2) - \alpha - \beta^T(a_1, a_2)$$

By combining the constraints function of IC and IR with (F_p), the multi-task principal-agent knowledge contribution model can be built as:

$$\max_{a_i, \beta^T}\max_{a_i, \beta^T} F_p = \pi(a_1, a_2) - \alpha - \beta^T(a_1, a_2)$$
$$s.t.\begin{cases}\max_a\max_a F_a = \alpha + \beta^T(a_1, a_2) - C(a_1, a_2) - \frac{1}{2}\rho\beta^T\Sigma\beta & (IC)\\ \alpha + \beta^T(a_1, a_2) - C(a_1, a_2) - \frac{1}{2}\rho\beta^T\Sigma\beta \geq \omega & (IR)\end{cases}$$

V. RESULT ANALYSIS AND DISCUSSION

A. Optimal solution of the principal-agent model

According to the incentive compatibility constraint(IC), the agent gains the optimal revenue when:

$$\frac{\partial F_a}{\partial a_i} = 0$$

Thus,

$$\frac{\partial\beta}{\partial a} = \begin{bmatrix}\frac{\partial\beta_1}{\partial a_1} & \frac{\partial\beta_1}{\partial a_2}\\ \frac{\partial\beta_2}{\partial a_1} & \frac{\partial\beta_2}{\partial a_2}\end{bmatrix} = \begin{bmatrix}c_{11} & c_{12}\\ c_{21} & c_{22}\end{bmatrix}, \quad \frac{\partial a}{\partial\beta} = \begin{bmatrix}c_{11} & c_{12}\\ c_{21} & c_{22}\end{bmatrix}^{-1};$$

it denotes that the unit change of the agent's effort cost is equal to the sensitivity of the agent's effort level reacting to the incentive cost.

When the optimum condition as $\frac{\partial F_p}{\partial\beta} = 0$, the total revenue of the principal is the largest by the participation constraints(IR); accordingly:

$$\frac{\partial F_p}{\partial\beta} = \left(\frac{\partial\pi}{\partial a}\right)^T\left[c_{ij}\right]^{-1} - \beta^T\left[c_{ij}\right]^{-1} - \rho\beta^T\Sigma = 0,$$

and $\beta = (I + \rho\left[c_{ij}\right]\Sigma\beta)^{-1}\frac{\partial\pi}{\partial a}$.

As ε_1 and ε_2 are respectively independent, and covariance (Σ) is a diagonal matrix, then $\beta = (I + \rho\left[c_{ij}\right]\sigma_i^2)^{-1}\frac{\partial\pi}{\partial a}$.

In order to simplify the process, setting $\frac{\partial\pi}{\partial a} = \theta$, and the meaning of (θ_1, θ_2) is the marginal revenue derived from the efforts spent on the two tasks.

Thus $\beta = \frac{\theta_i}{I + \rho\left[c_{ij}\right]\sigma_i^2}$,

β is a decreasing function of effort cost coefficient (c), risk aversion (ρ) and uncertain risk (σ).

Because the knowledge participation contribution behavior of the agent can be recorded by using information measures, the principal can fully observe the degree of effort

of knowledge participation contribution of agent, hence $\sigma_2^2 = 0$.

However, it is difficult to inspect the effort of knowledge creation contribution owing to the different knowledge levels of agents, and the inability of measuring tacit knowledge in their minds.

B. Principal-agent model analysis and discussion

In light of the above analysis, it can be considered that there are three kinds of relationship between knowledge creation contribution and knowledge participation contribution, which are mutually independent, complementary and replaceable.

(1) When the knowledge creation contribution and knowledge participation contribution of the agent are independent of each other ($c_{ij} = 0,\ i \neq j$), which shows that the rising effort cost of one party would not cause the change of the cost of the other party.

$$\begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix} = \begin{pmatrix} \dfrac{\theta_1}{1+\rho c_{11}\sigma_1^2} \\ \theta_2 \end{pmatrix}$$

Due to the independence of two effort cost coefficients, the incentive coefficients (β_i) of the two tasks are also independent. The incentive coefficient of knowledge creation contribution (β_1) is a decreasing function of effort cost coefficient (c_{11}), risk aversion (ρ) uncertain risk (σ_1^2), as shown in Figure 3.

The lower the risk aversion of the agent is, the higher the incentive intensity of knowledge creation should be given.

With the rising of marginal cost of knowledge creation, the principal should reduce the incentive intensity of it, while giving more incentives to knowledge participation contribution.

The principal should consider reducing the incentive intensity (β_1) and giving more fixed remuneration (α) when the uncertain risk increases.

(2) When the knowledge creation contribution and knowledge participation contribution of the agent are interdependent ($c_{ij} \neq 0$), which demonstrates that change in one job's effort cost will lead to a change in the marginal cost of the other task.

$$\begin{pmatrix} \beta_1 \\ \beta_2 \end{pmatrix} = \begin{pmatrix} \dfrac{\theta_1}{1+\rho c_{11}\sigma_1^2} \\ \theta_2 - \dfrac{\rho c_{21}\sigma_1^2}{1+\rho c_{11}\sigma_1^2}\theta_1 \end{pmatrix}$$

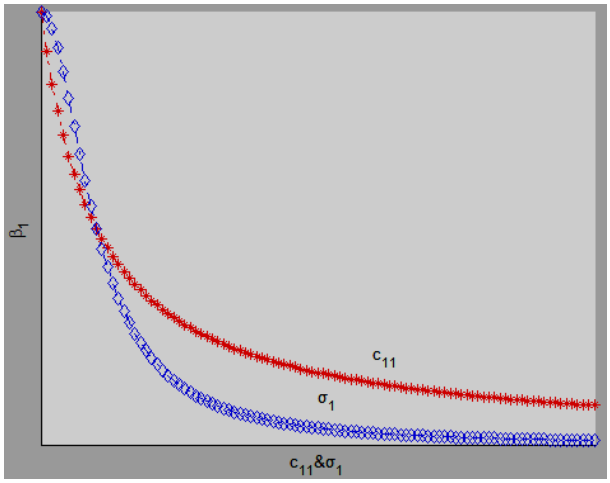

Fig3. The incentive coefficient of knowledge creation contribution (β_1) changes with c_{11} or σ_1^2.

The formula points β_1 has no relationship with $c_{ij}(i \neq j)$, namely, the incentive intensity of knowledge creation is independent of the relationship. The incentive intensity (β_1) should be increased with the increase of the marginal revenue θ_1, and be decreased with the increases of the risk aversion (ρ), the effort cost of knowledge creation (c_{11}) and the uncertain factors (σ_1^2).

Besides, the discussion of incentive coefficients of knowledge participation contribution (β_2) can be divided into two different cases.

When the knowledge creation contribution and the knowledge participation contribution of the agent are complementary to each other ($c_{ij} < 0, i \neq j$). Because $c_{21} < 0$, β_2 should be increased as the marginal cost of effort (c_{21}) and the marginal revenue of the knowledge creation (θ_1). Therefore, enterprises should increase incentive intensity of the knowledge creation and knowledge participation contribution, so that the overall knowledge contribution output of staff would be improved.

When the knowledge creation contribution and the knowledge participation contribution of the agent can be replaced with each other ($c_{ij} > 0,\ i \neq j$). As $c_{21} > 0$, β_2 should be decreased with the increase of the marginal cost (c_{21}); that is to say, when knowledge creation contribution can be replaced by knowledge participation contribution, enterprises should reduce the incentive intensity of knowledge participation contribution. Employees will participate in the knowledge participation for getting a higher

knowledge contribution output if β_2 is comparatively high, while ignoring the contribution of knowledge creation. Consequently, enterprises should reduce β_2, prompting the staff to contribute knowledge creation, as shown in Figure 4.

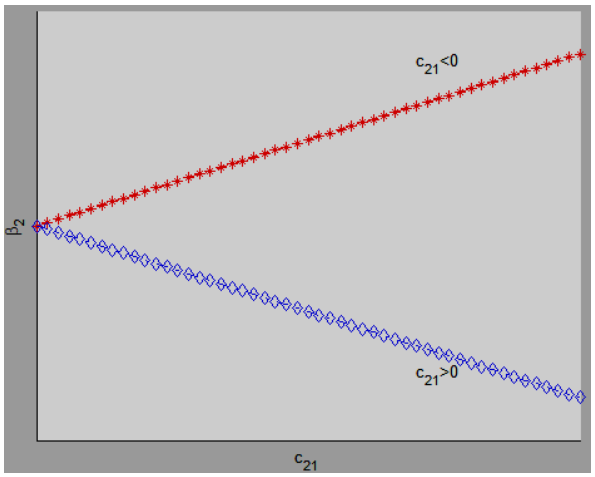

Fig4. The incentive coefficient of knowledge participation contribution (β_2) changes with c_{21} .

After all, when knowledge creation and knowledge participation are interdependent, incentive of knowledge creation contribution has nothing to do with the relationship between them, but the incentive intensity of knowledge participation contribution is associated with the relation between the two.

VI. CONCLUSION

In this paper, a multi-task principal agent model is built to analyze the incentive measures of knowledge contribution. The principal-agency theory and mechanism design theory is applied by considering the multi-task of knowledge creation and participation. The main results are as follows:

(1) In generally, the two tasks of knowledge creation and participation are mutually interdependent. Knowledge created by a staff is not valuable until the others read, evaluate and use it. Staff's knowledge creation behavior and positive participation behavior play a mutual promoting role in advancement of enterprise knowledge.

(2) What is more, the effort cost coefficient ($c_{ij} > 0,\ i \neq j$) is more common in many cases; knowledge creation contribution and knowledge participation contribution are replaceable with each other. Under the circumstances, if the enterprise's incentive intensity of the knowledge participation is set too high, employees will focus on the participation and usage of the enterprise knowledge base, while ignoring the creation of new knowledge, which will cause lack of new creative knowledge in enterprise. The effective way to solve this problem is transforming the substitution relationship between the two tasks into complementary relationship ($c_{ij} < 0,\ i \neq j$). Therefore, enterprises should set up respective target levels of both knowledge creation contribution and knowledge participation contribution, making them irreplaceable to each other.

The results will help enterprises to design different incentive intensities for knowledge creation contribution and participation contribution, and promote the continuous development of enterprise knowledge base. In further studies, evaluation method and empirical study of knowledge creation and participation contribution are required.

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