KNOWLEDGE SHARING MODEL AND ITS IMPLICATION ON KNOWLEDGE CATEGORIZATION AND MANAGEMENT

S. Ping Ho
Associate Professor
Dept. of Civil Engineering
National Taiwan University
1 Roosevelt Rd. Sec. 4, Taipei, TAIWAN
spingho@ntu.edu.tw

Pei-Chi Wu
Graduate Research Assistant
Dept. of Civil Engineering
National Taiwan University
1 Roosevelt Rd. Sec. 4, Taipei, TAIWAN
r93521712@ntu.edu.tw

Yaowen Hsu
Assistant Professor
Dept. of International Business
National Taiwan University
1 Roosevelt Rd. Sec. 4, Taipei, TAIWAN
yhsu@mba.ntu.edu.tw

Abstract: Recently, Knowledge Management (KM) has been applied to business management practice. Surprisingly, there are few studies that address the most fundamental problem in KM: people may prefer not to share their knowledge in order to preserve their intellectual or proprietary values in the organization. Without the premise of each individual's willingness to share knowledge, there will be no valuable input for the information-technology system and thus no knowledge management at all. This paper aims to model the behavioral dynamics of knowledge sharing and to design an incentive system that may facilitate knowledge sharing. In this paper, a game-theory based model is developed, and the framework for designing an incentive system is proposed according to the model.

Keywords: Knowledge Management, Knowledge Sharing, Knowledge Categorization, Game Theory

1. INTRODUCTION

Knowledge Management (KM), originated from the resource-based theory that treats valuable resources as the cornerstones of competitive advantages, has drawn immense attentions from practitioners and researchers in many industries. Grant [1] argues that knowledge has emerged as the most strategically significant resource of the firm, and the integration of individuals' specialized organizational capability is crucial to the creation and sustainability of competitive advantages.

Recently, KM has also been applied to business practice, and there have been many discussions regarding how to implement certain information technologies that may facilitate knowledge accessibility. Surprisingly, there are few studies that address the most fundamental problem in KM: people may prefer not to share their own knowledge in order to preserve their intellectual values in the organization. Without the premise of each individual's willingness to share knowledge, there will be no valuable inputs for the KM. Therefore, when organizations consider the implementation of costly Information and Communication Technology (ICT) platforms for KM, it is critical to assure that individuals are willing to share their knowledge through the platforms.

Since the sharing of knowledge relates to the competitive and cooperative relationships between different members in an organization, we consider game theory as a natural methodology to analyze such knowledge-sharing problems. In this paper, a game-theory based model will be developed. The model considers the knowledge characteristics and how each rational individual reacts, in terms of sharing knowledge, to these characteristics in equilibrium. We expect this study to provide both researchers and practitioners a new conceptual tool for understanding when and how knowledge will be shared.

2. METHODOLOGY

Game theory can be defined as the study of mathematical models of conflict and cooperation between intelligent rational decision-makers. Among economic theories, game theory has been successfully applied to many important issues. The basic concepts of game theory are discussed in this section.

2.1 Types of Games

There are two basic types of games: static games and dynamic games, in terms of the timing of decision making. In a static game, the players act simultaneously. On the contrary, in a dynamic game, the players act sequentially. Due to the nature of knowledge sharing, the dynamic game will be used for modeling here. Players in a dynamic game move sequentially instead of simultaneously. It is more intuitive to represent a dynamic game by a tree-like structure, also called the "extensive form" representation. Note that the players of a game are assumed to be rational; i.e., the players will always try to maximize their payoffs.

2.2 Game Solution: Nash Equilibrium

As to answer what each player will play/behave in this game, we shall introduce the concept of "Nash equilibrium," one of the most important concepts in game theory. The Nash equilibrium is a set of actions that will be chosen by each player. In other words, in a Nash equilibrium, each player's strategy should be the best response to the other player's strategy, and no player wants to deviate from the equilibrium solution. Thus, the equilibrium or solution is "strategically stable" or "self-enforcing" [2]. A dynamic game can be solved by maximizing each player's payoff backward recursively along the game tree. We shall apply this technique in solving the knowledge sharing game.

3. MODEL OF KNOWLEDGE SHARING

Based on game-theoretic analysis, the model is expected to solve for the conditions that determine the knowledge sharing behaviors of employees. Particularly, we want to know when sharing is possible and when it is impossible, whether the sharing needs any incentives provided by the firm. The implications for KM will be derived from the model. Knowledge sharing in organizations is for the purpose of knowledge transfer. Therefore, it is essential to ask: how knowledge is transferred? Two forms of knowledge transfer will be defined in answering the question.

3.1 Knowledge and Knowledge Transfer

Knowledge owned by human beings exists in human brains. According to Polanyi [3], knowledge can be categorized as: 1.explicit knowledge, which is relatively easy to encode and transmit in systematic language, and 2.tacit knowledge, which is difficult to formalize and communicate. From this perspective, the knowledge transfer should be similar to that in communication. Robbins and Decenzo [4] described the major activities in communication process.

3.2 Tacit-process and Explicit-process

We define, first, the process of sharing in the tacit form as the "tacit-process", and second, the process of sharing in the explicit form as the "explicit-process." In organizations, when individuals need certain knowledge possessed by others, they may need the knowledge owners to share the knowledge. First, they have to identify and locate the knowledge owners, and then, they establish contact with the knowledge owners and hope that the knowledge owners are willing to share. If the sharing is of the "explicit-process," individuals can ask for the documents regarding the knowledge if the sharer has documented or plans to document the specific knowledge. On the contrary, if the sharing is of the "tacit-process," individuals must interact with the sharer through face-to-face communication for learning the knowledge.

3.3 Functions of ICT Platforms in Knowledge Sharing

Although there is no standard specification for ICT platforms, this study shall define two types of platforms in terms of their functions in knowledge sharing. The first type is called "explicit-process platform," where sharers place the knowledge documents on the platform so that others can locate and download them in a very short period of time. The platform can disseminate the shared knowledge to more employees in organizations who need the knowledge and amplify the benefit of knowledge sharing. The benefits of the explicit-process platforms also depend on the ways of transmitting documents and the spreading velocity of the knowledge. The second type of ICT platform in this study is called "tacit-process platform." This platform is to facilitate the knowledge sharing in the tacit-process. Several studies, such as Bartol & Srivastava [5]. Davenport & Prusak [6], Cabrera [7], Pascarelia [8], suggest that a useful approach for tacit knowledge sharing is to develop various internet-based communities where employees and experts with specific knowledge or skills can gather together to share their knowledge through discussion. The community platform is expected to facilitate individuals in organizations raising and answering questions, or debating over more complicated issues. Through the tacit-process platform, the frequency of either individual or collective communication is increased, and the knowledge that is difficult to express in explicit forms may be better retrieved and extracted. Furthermore, the content of the communication about the non-codifiable knowledge can be electronically recorded and integrated by the platform, and then be stored in the organizational knowledge database for later sharing purposes.

3.4 Definition of Model Parameters

The model parameters could be divided into two sets, where one set concerns the employees and the other set concerns the firm. First, the employees make their decisions about sharing only based on their received net payoffs. If the employees have higher net payoffs for sharing their knowledge, they will choose to share, and vice versa. Second, the firm concerns only the net monetary benefit obtained, and will choose the decisions that maximize monetary payoffs.

3.4.1 Parameters Regarding Employees

Since our model does not involve uncertainty and the utility function is an increasing function of the monetary term, the game equilibrium in monetary terms will be consistent with that in utility form.

γ_1 : Explicit cost of sharing knowledge

The explicit cost exists because to share their knowledge to others, individuals have to invest time, effort, or money. Therefore, one of the factors that individuals consider to share or not is the magnitude of the cost. The higher the cost is, the less the individuals are willing to share. Nevertheless, the tacit-process platform could help to reduce decrease the explicit cost through faster and more frequent communication. From this perspective, γ_1 would be reduced more significantly in larger firms.

γ_2 : Implicit cost of sharing knowledge

When individuals share their knowledge, they may incur a hidden cost, due to the fact that their competitiveness and uniqueness in the organization may decrease after sharing their specific knowledge. Such cost is defined as the "implicit cost" of knowledge sharing. The magnitude of the cost depends on how unique, scarce, or important the knowledge is in an organization. The implicit sharing cost is related to how the human capital market values their knowledge or specialty. It is assumed that the ICT platform has no effect on reducing the implicit sharing cost.

s : Side benefit of sharing knowledge

As individuals share their knowledge in organizations, they may get positive feedback from their colleagues, and such feedback is considered the "side benefit." For example, in a

two-person work team, the experienced individual may want to teach the inexperienced one some basic knowledge or skills, so that the task load of the experienced one can be shared and the task could be completed more efficiently. In this case, the benefit to the experienced one is regard as the "side benefit of sharing knowledge." Sometimes one shares knowledge in order to gain respect from colleagues or build up professional authority in a particular knowledge domain. Such side benefit of sharing knowledge can be significant.

ω : Rewards for sharing knowledge

If the individual's knowledge is valuable for organization, yet the sharing of the knowledge has negative overall payoff to the individual, the organization may promote the sharing through the monetary reward.

3.4.2 Parameters Regarding the Firm

It is assumed that the firm will formulate strategies for knowledge management system, such as organizational structure and incentive system, based on the maximization of firm's profit. Major model parameters are defined as follows.

c_R : Firm's costs for providing monetary rewards

Under certain conditions as we shall discuss later, it would be beneficial for firms to provide monetary rewards for the knowledge sharing. c_R will be one of the decision factors for organization in developing knowledge management strategy.

c_T : Cost of tacit-process platform implementation

c_T includes the initial costs for the ICT module and the costs of platform management.

c_E : Cost of explicit-process platform implementation

π_T : Profits from knowledge shared via tacit process

Note that here π_T is independent of the tacit-process platform. Knowledge of tacit type can also be shared without the ICT platform. In fact, π_T should be considered or defined by imaging that there is no ICT platform. The impacts of ICT platform on π_T will be given later.

π_E : Profits from knowledge shared via explicit process

The definition of π_E is similar to that of π_T except that the sharing process is explicit-process.

3.5 Tacit Sharing Process Through ICT Platforms

The functions of ICT platform here are to provide individuals who demand or own certain knowledge a platform to communicate and interact more easily via explicit or tacit process. Therefore, tacit knowledge could be retrieved, extracted, and absorbed more effectively because of frequent communication and interaction on the platform. As a result, the amount of tacit knowledge extracted and shared relies on the number of people who utilize and benefit from the ICT platform. Accordingly, we shall define an efficiency coefficient, d_T, of the explicit sharing cost in the model.

d_T : Efficiency coefficient of the explicit sharing cost, γ_1.

d_T is due to the advantage of ICT platforms, the firm's scale (the numbers of employees), the number of individuals who demand and own knowledge, and the time and forms of communication and interaction. When d_T is high, the explicit cost of sharing knowledge will be small.

π_D : Added value of documenting tacit communication

Tacit-process platform can also bring additional value to organizations. During the tacit sharing process through the platform, the contents of the communications can be recorded, integrated, and then stored and maintained in a database for future reference, so that the tacit knowledge can be re-used and distributed as in explicit knowledge.

3.6 Explicit Sharing Process Through the ICT Platform

The functions of ICT platform for explicit knowledge is to provide a platform where the individuals can document their explicit knowledge and store the documents, the documents can be located and downloaded rapidly and easily when the knowledge is in need. Moreover, ICT platform also plays the role of an announcer or a library to promulgate and list the new and old explicit knowledge in it, so as to let others know the existence of the knowledge. Thus there is the dissemination effect through the ICT platform in the explicit-process.

d_E : The multiplier of π_E

We define a multiplier refer to that more benefit for firms could be resulted in sharing rapidly through the explicit-process ICT platform.

3.7 Knowledge Sharing Model

We assume that knowledge sharing game is a dynamic game with complete information, where firms provide the environment for knowledge sharing first, and then employees decide to share or not. Figures 1 and 2 show the game trees of knowledge sharing through explicit-process and tacit-process, respectively. As shown, there are two players in the game, the employee and the firm. At every node of employee's turn, the employee has two choices: "Share" or "Not share." For the firm, there are two types of nodes. At the first node, the firm decides whether or not to implement ICT platform by incurring the platform cost; i.e., "ICT platform" or "No ICT platform." At the firm's second node, the firm decides whether or not to reward the employee for the knowledge sharing behavior; i.e., to have "Rewards" or "No rewards."

In the game tree in shown Fig.1, the knowledge could be transferred in the explicit-process. Here the ICT platform refers to the explicit-process platform. On the contrary, Fig.2 shows the game tree where the knowledge has to be transferred in the tacit-process and the ICT platform is the tacit-process platform.

The payoffs of the players are modeled as shown in Fig. 1 and 2. For example, for the path [ICT platform, Rewards, Share] in the explicit-process game tree shown in Fig.1, the payoffs for the firm are $d_E\pi_E - c_E - c_R$, and the payoffs for the employee are $s + \omega - \gamma_1 - \gamma_2$. Note that the term $d_E\pi_E$ is due to the scale effect brought by the platform. The derivation of other payoffs in the tree is also straightforward and can be found in a similar way. Also note that the term $(1/d_T)\gamma_1$ in Fig. 2 is because of the reduction of explicit sharing cost contributed by the platform.

The strategic decisions of the firm in knowledge management and the sharing decision of the employees shall be made depending on the characteristics of knowledge and the environments of the firm. For example, if, to the sharer, the knowledge is an important know-how that maintains the sharer's uniqueness in the firm, then the sharer will ask for a substantial compensation for sharing the knowledge.

By solving the game trees in Fig. 1 and 2 backward recursively, we will obtain twelve possible game equilibria, and the corresponding conditions of each equilibrium as shown in Figure 3. Due to the length limit, the detailed conditions and their derivations of each equilibrium will not be shown here. However, we categorize each equilibrium according to the characteristics of the major variables and table them in Figure 3. Furthermore, we shall categorize knowledge based on the equilibria characteristics as shown in Fig. 3. Six types of knowledge are identified or categorized as shown in Fig. 4. In what follows we will discuss their implications for knowledge management.

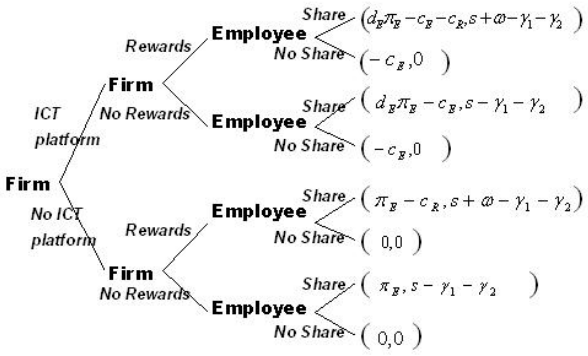

Fig. 1. Knowledge Sharing Game in Explicit Process

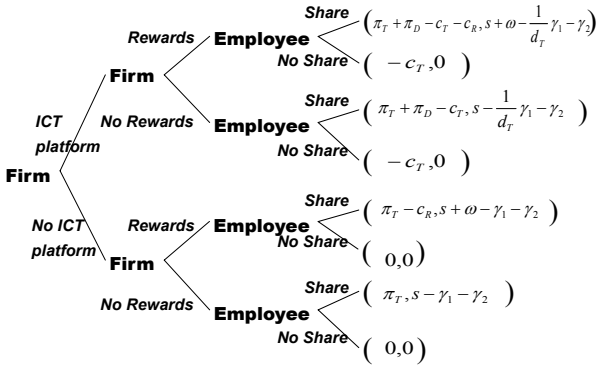

Fig. 2. Knowledge Sharing Game Tree in Tacit Process

	π (L)		π (H)	
	γ_2(L)	γ_2(H)	γ_2(L)	γ_2(H)
γ_1(L)	①	⑪	④	② ⑦
γ_1(H)	⑨ ⑩	⑫	③ ⑤ ⑥	⑧

Fig. 3. Game Equilibria Conditions

	π (L)		π (H)	
	γ_2(L)	γ_2(H)	γ_2(L)	γ_2(H)
γ_1(L)	Scale-insensitive simple knowledge	Expert knowledge	Scale-sensitive simple knowledge	Advantage added knowledge
γ_1(H)	Spurious knowledge		complex nonunique knowledge	

Fig. 4. Knowledge Categorization by Equilibrium Conditions

4. IMPLICATIONS FOR KNOWLEDGE CATAGORIZATIONS

Implications for knowledge management can be drawn from the equilibria of the game. The results of the game analysis show that the decisions concerning KM platform and incentives design are complex. For example, we learn that not every type of knowledge should be encouraged to share through a KM platform. Therefore, different strategies should be adopted for different characteristics of knowledge. We can further transform the game equilibria into two implications for knowledge management, namely, (1) how to classify knowledge for platform worthiness, and (2) reward incentives design. These implications are discussed as follows.

4.1 Knowledge Categorization for Platform Worthiness

Based on the game equilibria and three major dimensions implied by the model, we may categorize knowledge into several types concerning their worthiness of KM platform and reward incentives.

4.2 Simple Knowledge: Scale-sensitive Type or Scale-insensitive Type

This type of knowledge will generally yield Equilibrium 1 and 4. The sharing of such knowledge could emerge automatically. Simple knowledge is characterized by:

A. Explicit sharing cost: low. Low explicit sharing cost indicates that the knowledge can be easily integrated or documented without much time or particular efforts, and also can be shared and learned in daily routine interactions among employees or through simple documents.

B. Implicit sharing cost: low. Low implicit sharing cost shows that the sharing of the knowledge will not affect the sharer's competitive ability within organizations. For example, when many employees possess the same knowledge, or the knowledge can be easily acquired by employees.
C. The benefit of the firm due to shared knowledge: low to high. Whereas most simple knowledge, intuitively, may not be very valuable to a firm, but there may exist a synergy when a large number of simple knowledge is shared or a specific simple knowledge is shared to a large organization. This synergy may be due to the knowledge combination in the knowledge creation process. Consequently, firms will consider using the ICT platform for simple knowledge only when the scale effect exists even through the simple knowledge will also be shared without ICT platform. For the simple knowledge, if the scale effect exists for firms, we call the knowledge as Scale-sensitive simple knowledge; otherwise, the knowledge will be called Scale-insensitive simple knowledge.

The simple knowledge could be general concepts or skills, such as the use of MS Words, the proposal templates, task-related skills, or how to monitor a job site. In many cases, this type of knowledge may be just the so-called "tricks" that are easy but useful. A simple database system or sharing community platform would be sufficient for managing such knowledge.

4.3 Complex nonunique knowledge
This type of knowledge will generally yield Equilibrium 3, 5 and 6. The complex nonunique knowledge is characterized by:
A. Explicit sharing cost: high. Due to its complexity, this type of knowledge cannot be easily shared or learned. The sharing requires significant efforts or time to organize, document, or communicate the knowledge. Note that it is assumed previously that such complexity can be reduced by the ICT platform under in the tacit-process.
B. Implicit sharing cost: low. Although this knowledge type is not easy to be shared or learned, the uniqueness of the knowledge is low such that the sharing would not damage the competitiveness of the sharer seriously.
C. The benefit of the firm due to shared knowledge: high. The sharing of this knowledge may create higher synergy, and in general creates higher value than in the simple knowledge.

As mentioned previously, employees would not share the knowledge with high explicit sharing cost unless the firm rewards them for the cost. In explicit sharing process, a better strategy of the firm would be to provide the rewards for sharing because the sharer's cost cannot be reduced by the ICT platform. Nevertheless, there are two alternatives for firms to facilitate the sharing depending on the scale effect of the knowledge sharing in the tacit sharing process. If scale effect exists, firms can reduce the sharer's sharing cost through the ICT platform; while without scale effect, firms should reward the sharer to compensate for the sharing cost. Therefore, the knowledge sharing systems would be relied on the process of the knowledge sharing and scale effect.

For example, the experiences or lessons obtained in each assigned business project or consulting project can be considered as complex nonunique knowledge. If such knowledge is the main knowledge type in a larger consulting company, the ICT platform can help employees communicating their lessons learned more easily, and then organize lessons from individuals so as to create value for the firm. At the same time, the sharing of these lessons learned will not conflict with the sharers' competitiveness.

4.4 Advantage added knowledge
This type of knowledge will generally yield Equilibrium 2, 7 and 8. This type of knowledge is associated with a firm's competitive advantage. The advantage added knowledge is characterized by:
A. Explicit sharing cost: low to high. As a result, the explicit sharing cost is not the main factor to distinguish this knowledge.
B. Implicit sharing cost: high. The advantage added knowledge may usually be difficult to be obtained from others. As a result, the sharing of the advantage added knowledge would hardly occur because of the uniqueness of the knowledge. Employees will not share their knowledge unless they are rewarded by commensurate payoffs for the sharing.
C. The benefit of the firm due to shared knowledge: high. The advantage added knowledge will contribute significantly to a firm's competitive advantage after the knowledge is shared and learned by other employees.

While this type of knowledge will increase the competitive advantage of a firm, the sharing of such knowledge will also diminish the individual's competitiveness. Therefore, rewards are necessary for the individuals to share. Nevertheless, the benefit from sharing the advantage added knowledge does not necessarily justify the ICT platform that disseminates the knowledge. Therefore, the ICT platform decision for the advantage added knowledge should depend on the scale effect of the knowledge. Examples of such knowledge are the promotion ability of the super salesman in an insurance company, the R&D ability of the top engineer in a CPU manufacturer, and the managing ability of the project manager in a construction consulting company, etc.

4.5 Expert knowledge
This type of knowledge will generally yield Equilibrium 9, 10, 11, and 12. Firms need not do anything to facilitate the sharing of expert knowledge shared. The expert knowledge is characterized by:
A. Explicit sharing cost: low to high. For knowledge of a profession such as accounting, the explicit sharing cost is often very high. However, certain knowledge with low explicit sharing cost could also be included in this type of knowledge, such as the auditing tricks of a CPA. In some cases, knowledge of non-professional experts may also be easily transferred.

B. Implicit sharing cost: high. Experts learn their knowledge through extensive training or experiences. Usually, only very few people own expert knowledge in a firm, and thus they will be reluctant to share their knowledge to others to avoid that they may be substituted by others.
C. The benefit of the firm due to shared knowledge: low. Due to the low demand of this knowledge in a firm, the sharing and dissemination of the knowledge is not desired. Therefore, the firm's benefit from knowledge sharing is low.

Note that the term "expert" refers to some particular people who are professionally trained or very experienced. Furthermore, because only a few experts, such as lawyers, are needed in a firm, and the sharing of expert knowledge may not create synergy. For example, the sharing of the knowledge owned by CEO or CFO will not contribute too much to a firm's competitive advantage.

4.6 Spurious knowledge
Spurious knowledge will generally yield Equilibrium 9 and 10. Firms do not need to do anything to facilitate the sharing of spurious knowledge. The spurious knowledge is characterized by:
A. Explicit sharing cost: high. Sharing and learning such knowledge takes time and effort.
B. Implicit sharing cost: low. In firms, owning such knowledge does not lead to the uniqueness of the sharer in a firm, because the knowledge is not relevant to the competitive ability.
C. The benefit of the firm due to shared knowledge: low. Spurious knowledge will contribute little to firms.

The sharing of this type of knowledge would be unworthy to firms and may even create a negative effect, so that the manager may punish employees to avoid the sharing behavior.

4.7 Flowchart for KM Platform and Incentives Strategy
After the analysis of the sharing game, we may further summarize a flowchart for KM strategies as shown in Fig. 5. For example, if the simple knowledge is the main knowledge type within the organization, the rewards should not be considered as an instrument to promote sharing. Next, if there is scale effect, ICT platform will be justified.

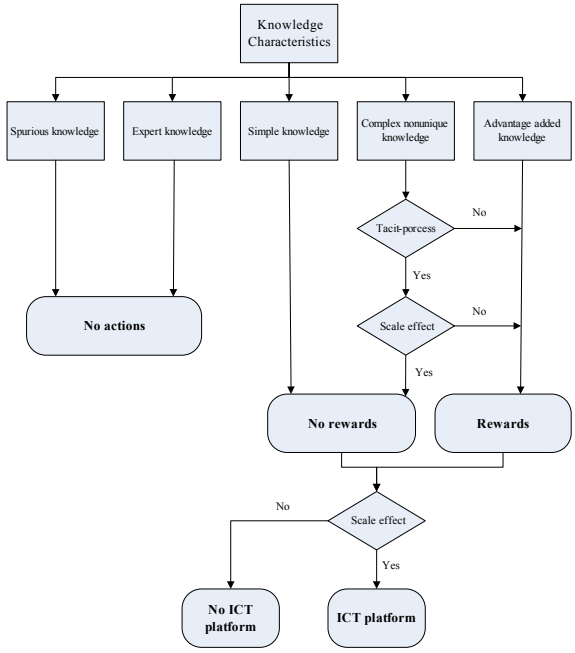

Fig. 5. Decision Making Process for KM

This model derives the conditions for determining the strategies of implementing ICT platforms and that of rewards. Specifically, we developed a decision flowchart for KM platform and incentives strategies.

5. CONCLUSIONS

In this study we have developed a game-theoretic model for analyzing the knowledge sharing behaviors and defined six types of knowledge. Each type of knowledge can be characterized by three dimensions: knowledge complexity implied by γ_1, knowledge uniqueness to sharers implied by γ_2, and the benefits from shared knowledge implied by π. We find that, from the perspective of knowledge sharing, only firms with simple knowledge, complex nonunique knowledge or advantage added knowledge deserve resources to facilitate the sharing.

6. ACKNOWLEDGEMENT

The work presented in the paper was supported by the National Science Council of TAIWAN, grants NSC94-2211-E-002-063.

REFERENCES

[1]Grant, R. M., "Prospering in Dynamically Competitive Environments: Organizational Capability as Knowledge Integration", Organization Science, Vol. 7, No. 4, pp. 375-387, 1996.
[2]Gibbons, R., Game Theory for Applied Economists. Princeton University Press, Princeton, N.J., 1992.
[3]Polanyi, M., "The Logic of Tacit Inference", Philosophy, 41(1): p.1-18, 1966.
[4]Robbins, S. P. and Decenzo, D. A., Fundamentals of Management, Prentice Hall, 2004.
[5]Bartol, K. M. and Srivastava, A., "Encouraging Knowledge: The Role of Organizational Reward Systems", Journal of Leadership and Organization Studies, Vol. 9, No. 1, 2002.
[6]Davenport, T. H. and Prusak, L., "Working Knowledge", Harvard Business School Press, 1998.
[7]Cabrera, A. and Cabrera, E. F., "Knowledge-Sharing Dilemmas", Organization Studies, vol. 23, issue 5, 2002.
[8]Pascarella, P. "Harnessing knowledge," Management Review, 86(9): 37-40, 1997.