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"The Evolution of C2"

Modeling and Optimizing the Motivation of Workers and Managers for Knowledge-Sharing: A Game-Theoretic Analysis

Topic 3: Information Sharing and Collaboration Processes and Behaviors

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Knowledge management (KM) is especially difficult to implement for project-based work. Tacit knowledge gained during projects diffuses when project teams disband and reform. Organizations are increasingly focusing on managing their knowledge flows, developing or investing in KM systems. Knowledge-sharing (KS) behaviors are the main input to KM systems, so we aim to optimize knowledge input to magnify the usefulness of KM systems. We adopt game-theoretic models to analyze workers' knowledge-sharing dynamics under different KM strategies, taking managers' viewpoints. We will solve Nash Equilibria by identifying associated conditions on each equilibrium path, and derive implications from these conditions for KM strategies. We will explore: (1) types of knowledge that deserve sharing; (2) types of employees that possess different knowledge; (3) incentives that cause the right individuals to share useful knowledge; and (4) costs and benefits associated with alternative company KM strategies. We plan to validate these theoretical results via an empirical study. This paper lays out the problem, discusses the key points of departure, and presents our initial version of a game tree for employees' decisions about knowledge sharing. Interviews will subsequently be conducted to validate the game tree, Nash Equilibria, and implications for knowledge management in project-based firms.
Keywords: Knowledge management; knowledge sharing; project-based firms; game theory; Nash Equilibrium.

Motivation

In the information age, decision makers are often overloaded with unnecessary and irrelevant information. However, if information can be transformed into actionable knowledge, decisions can be made more effectively. In the military, this transformation achieves command and control (C2) agility (Alberts and Hayes 2003). Moreover, because information is an important source of power, effective flow of information/knowledge to the "Edge" allows military and civilian leaders to delegate authority and power confidently (Alberts and Hayes 2003).

As Nissen (2006) found, knowledge flows can have significant effects on organizational performance. From Nissen's spiral knowledge-flow visualization, the first stage of knowledge flow (depicted in Figure 1) from A to B is socialization, which is also classified as "sharing" by Nonaka (1994). Recently, many large organizations, from manufacturing companies to engineering firms to the military, have devoted a great deal of attention and money to knowledge management, due to their need for sharing scarce, specialized knowledge—both technical and institutional (Javernick-Will, Levitt and Scott 2007). Acquiring and sharing internal knowledge, when the knowledge is owned by employees in an organization, is generally less expensive than acquiring knowledge externally. In order to facilitate better management of knowledge, many companies have developed Information and Communication Technology (ICT) platforms to motivate the transfer of knowledge within an organization and to enhance knowledge accessibility. These actions help to overcome a critical attribute of knowledge flow—**knowledge inertia** (Nissen 2006); however, the employees' willingness to share their knowledge freely is a requirement for ICT knowledge sharing platforms to be successful and useful (McQuary 2007).

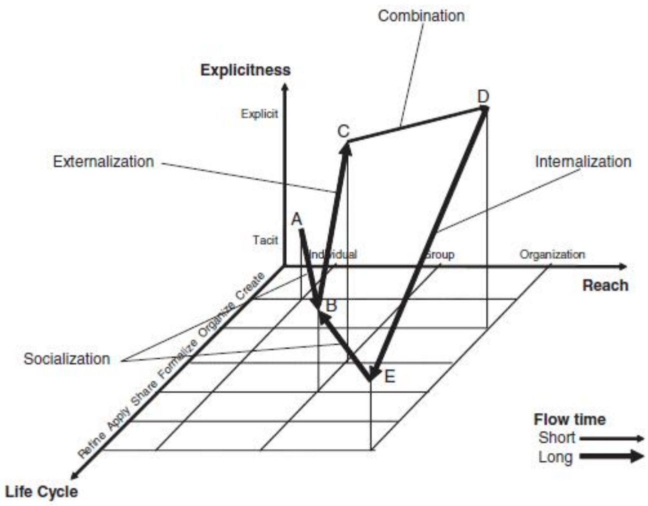

Figure 1. Nissen (2006)

Organizations investing in ICT platforms often face difficulties in encouraging their employees using ICT platforms to share their knowledge (A. Cabrera, E. F. Cabrera 2002). For example, Goh (2002) argues that a high level of mutual trust is necessary for this to happen. In addition, employees may be afraid of sharing their knowledge, because sharing their scarce knowledge might reduce their uniqueness, and hence their power or status. In other words, employees are often reluctant to share critical knowledge which is viewed as a source of power (Goh 2002; Ho et al., 2006, 2008). Surprisingly, few studies have addressed the most fundamental element in knowledge management: the willingness of employees to share their knowledge. Most KM literature tends to focus on the "technology side" of KM such as platform design and knowledge warehousing issues. Unfortunately, many KM attempts involving costly and advanced high-tech information and communication systems died when employees were not motivated to share knowledge. Thus, in our research we focus on the first stage of Nissen's knowledge-flow diagram, i.e., socialization/sharing, as a solid foundation for the following stages, to help organizations harness the power of their shared knowledge.

Research questions

The proposed research contributes to research area B of the C2 domain—Near-Optimizing Knowledge and Power Flows. We expect to answer the following three questions in order to help military, other governmental and civilian leaders and policy makers facilitate, enhance, measure, and ultimately optimize their organizations' knowledge flows:

What are the drivers of knowledge sharing behaviors in organizations?

We aim to study why employees decide to share or not share their knowledge. Are they dissatisfied with monetary rewards for sharing? Is their failure to share knowledge caused by factors such as excessive direct workload or not knowing with whom they can and should share?

What new knowledge taxonomy can be derived from the model of knowledge sharing dynamics and how can we identify and manage different kinds of knowledge?

We aim to develop a knowledge taxonomy to inform knowledge sharing strategies and the design of knowledge management systems and organizations. If knowledge sharing brings payoffs greater than zero, organizations should facilitate sharing this type of knowledge. On the other hand, if the sharing behavior costs more than the benefits it can bring, no or negative incentives should be implemented to discourage this type of unprofitable knowledge sharing

What are the model's implications for the design of knowledge management systems and organizations?

We build on the theory of knowledge sharing dynamics to advance the design of knowledge management infrastructure and platforms and organizational controls such as incentive systems, rewards, and organizational institutions. Furthermore, the interacting effects between KM infrastructure and organization structure on knowledge sharing may further complicate the KS problem. We expect to derive important requirements or characteristics of KM infrastructure from this new perspective.

Literature review

Transferability is one of four characteristics of knowledge that have critical implications for management (Grant 1996). Knowledge transfer requires communication, which involves four sequential steps—encoding, communicating, decoding and feedback—for the message to be communicated through the channel during the process (Robbins and Decenzo 2004). This process also corresponds to Polanyi's (1967) categorization of knowledge: (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 and is transferred through its shared application. However, we also seek to incorporate an important attribute of knowledge flow introduced by Nissen (2006) — **knowledge inertia**. Knowledge does not flow spontaneously; instead, immobilized knowledge tends to stay at rest. In order to mobilize knowledge, it is necessary to exert a force, either internal or external. Here we will focus on evaluating individuals' internal forces, i.e., willingness, to share their knowledge.

The construction industry and the military have many project-based activities. The fact that every project is unique increases the difficulty of capturing knowledge after projects are accomplished. Projects like this are "discontinuous organizations" over their life cycle. Team members join or leave the group while the work process is still on-going, due to the need for different skill requirements in each project phase to complete different parts of the process (Ibrahim and Paulson 2005). A flux of participants over the life of a project creates additional demands for effective knowledge sharing.

In fact, Knowledge sharing can be viewed as a paradigmatic social situation known as a "social dilemma" (Connolly and Thorn 1990). Social dilemmas describe paradoxical situations in which individual rationality—simply trying to maximize individual payoff—leads to collective irrationality (Kollock 1998) and the collective irrationality results in collective damage (A. Cabrera, E. F. Cabrera 2002) — in this case, no sharing of knowledge. Organizations require information exchanges to function well: Processing information enables them to coordinate their specialized and interdependent activities (Jin and Levitt 1996). Project-based sectors, in particular, understand that incomplete transfer of knowledge can cause unnecessary rework and delay (Paulson 1976; Jin and Levitt 1996). From Arthur Andersen Business Consulting (1999), we know that KM = (P+K)S where P stands for people, K stands for knowledge, and S stands for sharing. Although we find that increases in people, knowledge and sharing promote knowledge management linearly, an increase in multi-directional sharing leads to an exponential increase in knowledge management effectiveness. However, if the shared knowledge is not valuable to the receiver, "knowledge sharing" can lead to less productive organizations due to task interruption.

The reward system is another key element associated with the effectiveness of knowledge sharing because it affects employees' willingness to share what they know. Sometimes, knowledge sharing does not lead to short term financial benefits to organizations but it brings significant benefits in the long run. Hence, to promote knowledge sharing, the reward system should be broadly based on other dimensions of performance, such as successful knowledge sharing, co-operation, and teamwork, instead of on purely financial outcomes (Goh 2002). A good reward system should include fair assessment and explicit recognition of knowledge sharing in order to have a positive impact on knowledge providers (Bartol and Srivastava 2002). Moreover, according to Dyer and Nobeoka (2000), three methods to solve the knowledge sharing dilemma are (1) motivating employees and sharing knowledge openly, (2) preventing free riders, and (3) reducing the costs associated with valuable knowledge search and access.

The research builds primarily upon the research by Ho, Hsu, Wu, and Lin on implications of a game-theoretic knowledge sharing model (2006, 2008, 2009). Effective knowledge management systems can help organizations avoid "reinventing the wheel" (Levitt, Scott and Javernick-Will 2007). We extend previous knowledge management research by focusing on understanding and modeling workers' incentives to share knowledge, thereby enhancing the effectiveness and profitability of knowledge management systems. In the past, knowledge is classified into two groups, explicit knowledge and implicit or "tacit" knowledge. The categorization functions well in most cases but it is based on individuals' viewpoints. When military leaders manage knowledge in organizations, however, benefits to organizations acquired from knowledge sharing should be taken into consideration as well, in order to evaluate its profitability. Ho (2006) incorporated this critical factor and established a new framework for knowledge categorization, taking a higher organizational level viewpoint (Table 1). We will build on and refine his framework to develop a new knowledge taxonomy. Details are provided in the research design section.

Table 1: Ho's knowledge taxonomy, source: (Ho et al 2009)

		Value to firm, π			
		Low π		High π	
		Employees' implicit sharing cost, γ_2			
		Low γ_2	High γ_2	Low γ_2	High γ_2
Employee's explicit sharing cost, γ_1	Low γ_1	Simple Knowledge	Special Knowledge	Core Simple Knowledge	Core Unique Knowledge
	High γ_1	Spurious Knowledge		Core Complex Knowledge	

According to Ho et al. (2006) and Davenport and Prusak (1998), employees have three reasons to share their knowledge: monetary rewards, reputation and altruism. Interestingly, in a later empirical study by Ho et al. (2009), monetary rewards were found to have much less influence than either reputation or altruism on sharing behaviors of all types of knowledge. Furthermore, based on Ho at al. (2009), monetary rewards are not an effective approach to promote the sharing of desired or core types of knowledge for several reasons. The relatively small role of monetary reward was also noted in research conducted by Bobrow and Whalen (2002) on the well-known Xerox knowledge management system, "Eureka." In Xerox's widely admired Eureka system, service technicians stated that building a reputation for competence within their "natural community of practice" of fellow service technicians was a significant and major incentive for knowledge sharing. Including knowledge providers' names along with shared knowledge is one meaningful way to harness this important positive reinforcement for knowledge sharing (Bobrow and Whalen 2002).

We, therefore, build on and modify the knowledge sharing model developed by Ho et al. (2006). Ho's (2006) model was tested by an empirical study after the knowledge sharing model was built from an extensive literature review. This paper, in contrast, starts from combining results from his previous work as well as findings from several case studies with US construction firms using grounded theory case studies, as suggested by Eisenhardt (1989) to build a new game-theoretic model. We selected this research strategy because although a great deal of research has been conducted in the KM field, no strong theory has been developed, especially in the domain of KS behavior. We aim to develop a novel theory that is testable and empirically valid, so Eisenhardt's (1989) grounded theory development approach is appropriate. Thus, we will scrutinize the pattern of information collected from ethnographic interviews and incorporate Ho's previous findings to rethink what factors actually drive employees' KS behavior and build a new knowledge sharing model for further analysis and empirical testing.

We believe that a new game tree with these changes can represent the actual sharing mechanisms used by today's "Web 2.0" knowledge workers more accurately than prior models. Thus, we expect that the new Nash Equilibria in the revised game-theoretic model will provide more useful insights for managers of "Millennial" or "NetGen" workers who have grown up effortlessly sharing knowledge and information digitally from the time they first texted, emailed, blogged, Facebooked or Twittered (Wikipedia 2009).

Research Design

Game theory has been successfully applied to many important economic issues. Moreover, a game-theoretic model can be an appropriate tool to predict what the optimal strategies are for organizations and employees, and the equilibrium conditions. In this research, we will use game theory for theoretical investigation and analysis. Although we replicate Ho's analysis steps, we have modified his game-theoretic model to derive new implications.

Before building the new game-theoretic model, ethnographic interviews with US construction firms are being used to gain insight about the drivers of knowledge sharing behavior. Ho's empirical study (2009) that examined employees' sharing attitude shown the necessity of refining the game-theoretic model used in that study, since monetary rewards were designed as a major factor affecting employees' knowledge sharing behavior, but monetary rewards have been shown there and in other US-based studies to be a less important factor than reputational rewards and altruistic rewards. Therefore, the new game-theoretic model will increase the level of importance of reputational rewards and altruistic rewards, decrease the level of importance of monetary rewards, and, meanwhile, incorporate new insights from ethnographic interviews.

Key concepts in game theory used in this research are introduced as follows:

Nash Equilibrium:

Knowledge sharing behavior within organizations involves a trade-off between costs and payoffs. In game theory, people are assumed to be rational and a Nash Equilibrium is a set of choices by all of the players in the "game" which can be viewed as "strategically stable" or "self-enforcing" because no single player can improve her/his payoff in the game by unilaterally deviating from their current choice (Gibbons 1992). Simply put, this strategy is the best response by each player to other players' current choices. So it is inherently stable and is resistant to attempts by any individual or group to change it, even if it is not optimal for the whole organization.

Types of games:

In game theory, games are classified by the completeness of information as well as the way in which games are played (i.e., static games versus dynamic games). We will use a dynamic game with perfect information because: (1) players are able to observe others' actions and (2) the game involves a series of sequential interactions between organizations and employees. A dynamic game model for knowledge sharing with perfect information can be defined, involving three steps. First, player 1 plays his strategy (organizations decide whether to install ICT platform). Second, player 2 observes player 1's strategy. Finally, player 2 plays his strategy (employees decide whether to share their knowledge) and the game ends.

Backward Induction Solution:

As rational players, they will choose the strategy which maximizes their benefits among these options and thus a backward induction solution will be utilized in this research. The backward induction method is described as follows:

$$\max \pi_2 (a_1, a_2)$$

Given the action a_1 previously chosen by player 1 for each scenario, the strategy that enables player 2 to maximize his payoff is his best response denoted by $R_2 (a_1)$.

$$\max \pi_1 (a_1, R_2 (a_1))$$

Since player 1 should anticipate player 2's reaction, $R_2 (a_1)$, player 1 wants to maximize his payoff when player 2 plays $R_2 (a_1)$. If player 1's best response is denoted by a1*, we call (a1*, R2 (a1*)) the backward induction solution

Model of Knowledge Sharing:

Figure 2 below shows the game tree developed by Ho et al. (2006). In the payoffs for each branch of the game tree (enclosed in parentheses on the right,), the expression before the comma is the organization's payoff, and the expression for the employee's payoff is shown after the comma. Building on the results from Ho's empirical study (Ho et al. 2009), we de-emphasize the monetary reward variable, ω, and we break side benefits, S, into two parts, altruism, A, and reputation, R. Figure 3 shows the initially revised game tree that will be utilized as a starting point for this research. We realize that it might be difficult for researchers, organizations and employees to determine the precise actual value of every single variable such as d, π, C_P, since the value could be subjective. Thus, we will focus on deriving qualitative implications from our game-theoretic model after Nash Equilibria and associated conditions have been identified.

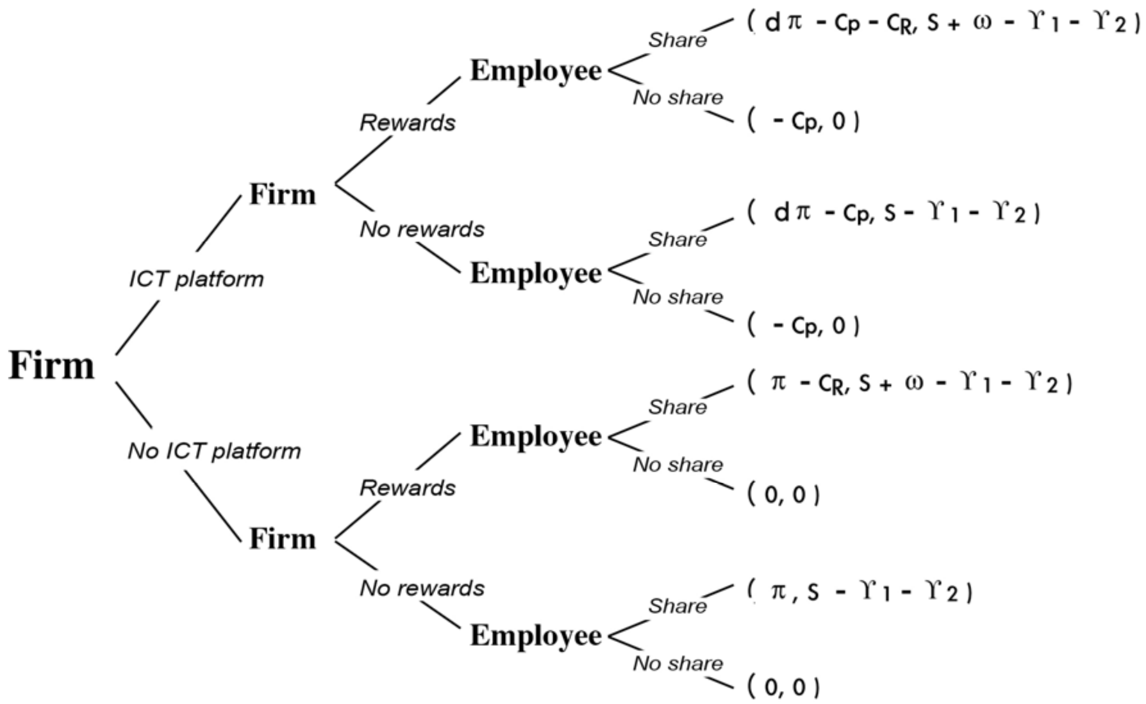

Figure 2. Game tree to be modified (adapted from Ho et al. 2006)

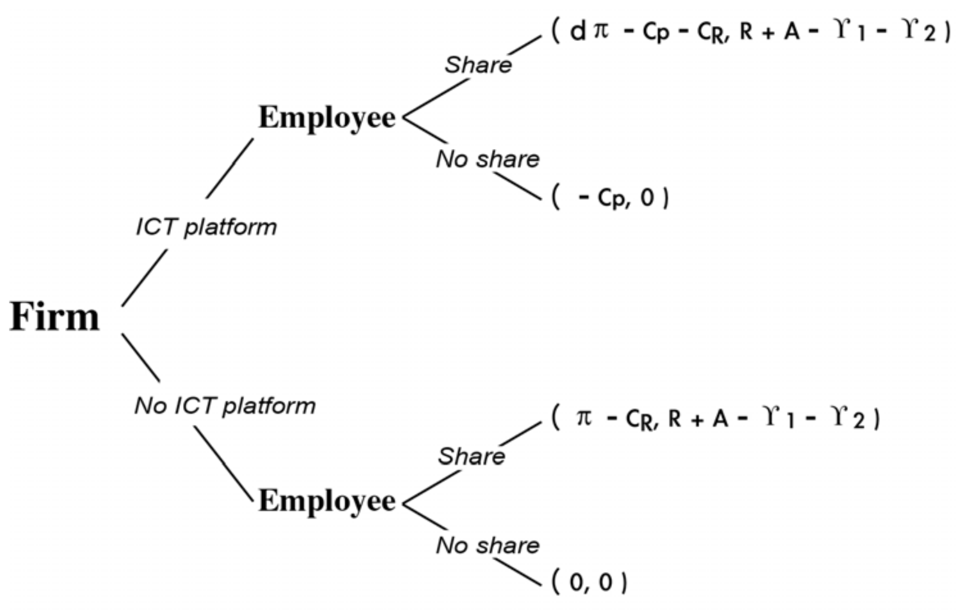

Figure 3. Modified game tree

Variables for employees:

γ_1: The explicit cost of sharing knowledge

The explicit cost results from necessary time, money and effort to share individuals' knowledge. Individuals are less willing to share their knowledge when this parameter is high.

γ_2: The implicit cost of sharing knowledge

After sharing their knowledge, individuals may incur undesirable hidden costs due to loss of power, status or uniqueness. Many organizations evaluate their employees in terms of relative performance, so employees are less willing to share specialized knowledge that they alone hold. The degree of the implicit cost depends on how rare or important the knowledge is perceived to be.

R: The benefits from special recognition (e.g., self-satisfaction, reputation)

In the Eureka case, the system offered something that Xerox technicians couldn't resist: the chance to share their successes with others in their copier technician "community of practice" on a global scale, in order to enhance their status in the copier technician community.

A: The benefits of helping others (i.e., Altruism)

E.g., feeling happy because of receiving smiles or thanks from colleagues.

Variables for organizations:

C_R: Organization's costs for providing monetary rewards

Organizations are willing to incentivize knowledge sharers if they bring companies positive payoffs. This cost of providing monetary incentives exists even if employees do not perceive these rewards as a meaningful incentive to share their knowledge.

C_P: The cost of the ICT platform installation and maintenance

π: Organization's benefit due to knowledge sharing

Employees can deliver higher performance by gaining useful and valuable knowledge, and thus increase the organizations' revenues and/or lower its costs.

System-related variables

d: The multiplier, π, of organizations' benefits

The ability for employees worldwide to share their knowledge rapidly through an ICT platform can multiply the benefits organizations obtain by capturing and sharing knowledge.

Please note that, the initially revised game-theoretic model shown in Figure 3 is likely to be further modified as our ethnographic interviews proceed. Ethnographic interviews are used here because building a novel theory requires flexibility and adjustment (Eisenhardt 1989). We expect to find different Nash Equilibria and associated conditions from the new game-theoretic model by replicating Ho's (2006) reasoning process.

Conclusion

This research has been designed to respond to Ho et al.'s (2009) urge for a refinement of the game-theoretic model built in 2006. The researchers are in the process of conducting ethnographic interviews to refine the original model. Our goal is to develop more precise knowledge management strategies by using the new game-theoretic model to analyze the dynamics of knowledge sharing behavior. Based on the new game-theoretic model, a new knowledge taxonomy is also expected to be introduced. An empirical study will subsequently be conducted to validate our theoretical results.

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