2014 47th Hawaii International Conference on System Science

Incentive Issues and Solution Mechanisms for Knowledge Transfer with Enterprise 2.0 Technologies: A Game-theoretic Approach

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Abstract

Firms increasingly use enterprise social media for knowledge activities such as knowledge transfer. In an enterprise setting, it is often the case that the receiver of transferred knowledge will make decisions that have ramifications for the knowledge sender. Using a game-theoretic approach, this paper studies the consequences when a knowledge sender has incentive to transfer knowledge strategically and the mechanisms that can be designed to deter such strategic behavior. We find that knowledge transfer may fail when senders transfer knowledge strategically, but knowledge receivers can design a probabilistic auditing mechanism to ensure truthful knowledge transfer. Our results suggest that a knowledge receiver's own knowledge can facilitate truthful knowledge transfer, but the receiver should not let her own knowledge be known by the sender. This research contributes to the knowledge management literature, and has interesting implications for the adoption and use of enterprise social media.

1. Introduction

Firms are increasingly using social media technologies, such as blogs, wikis, tagging, social networking, and information markets, for knowledge work in an enterprise environment [10, 14]. In particular, companies tap into Enterprise 2.0 technologies for corporate decision making, which is dubbed as "Decisions 2.0" [2]. While extant research has largely focused on how these technologies can improve decision making, it is important to understand the challenges these approaches present.

One issue is that when a decision maker seeks knowledge to inform decisions, some individuals may transfer distorted knowledge in order to influence the course of action. Such concerns have led to the shutdown of the prediction market planned by the Defense Advanced Research Projects Agency (DARPA) in 2003. DARPA created an extensive prediction market called the Policy Analysis Market (PAM) to help decision makers predict geopolitical events. The Senate decided to shut down the program before its launch out of fears that terrorists would try to manipulate prices in the prediction market in order to distort the information reaching decision makers [8, 19].

When corporate executives seek input for decision making in an enterprise environment, while there may be no concerns for terrorists, it is usually the case that the decisions to be made have important implications for the employees, who are also the sources of knowledge. For example, Ford and Sterman [6] documented that the project team leaders of a contractor were known as a "liar's club" because they concealed problems and delays when reporting the progress of their subsystems at weekly meetings. The following hypothetical example further explains how knowledge senders may have incentives to transfer distorted knowledge.

Suppose a company is considering whether to adopt radio frequency identification (RFID) technology for its inventory systems. The scientific knowledge about the technology is not an issue for the company; the question is whether RFID works for the company, or more precisely, whether the company is better off adopting RFID than not. The net benefits of implementing the technology depend on many factors, such as the current status of the firm, the suppliers, the clients, the competitors, and the business environment; the required changes to the firm's structure, processes, and personnel; etc. Given the complexity of the decision, both internal inputs from employees of various roles and levels and external advice from business partners and consultants may be solicited. Each party, however, when providing their information and knowledge, is fully aware that their inputs may influence the decision one way or another, which may in turn affect them. For example, the CTO realizes that implementing the RFID technology helps entrench his position in the organization, and thus may intentionally present information that favors the new technology. For another instance, employees with positions likely

978-1-4799-2504-9/14 $31.00 © 2014 IEEE
DOI 10.1109/HICSS.2014.503

to be eliminated by the adoption of RFID technology have incentives to provide information that supports the choice of keeping the current system.

In addition to knowledge distortion, another potential problem with knowledge transfer using Web 2.0 technologies is that one may attempt to influence the decision making process in ways that are beneficial to him, even though he does not possess knowledge. An example of this is the "yes men" phenomenon: a subordinate chooses to always agree with the supervisor [15]. McAfee [14] points out that in the context of Enterprise 2.0, authority in a company may "exert all kinds of subtle and not-so-subtle leverage over online content" and raises a series of questions expressing concerns for the "yes men" problem: "Will they (a company's leaders) be able to resist the temptation to silence dissent? What will happen, for example, the first time someone points out in their blog that an important project is behind schedule and that corners are being cut? What will happen if the content on the new platform is uncomfortable for powerful people within a company?" Burris et al. [3] show that possible negative outcomes deter employee voice in an organization. It should be noted that the "yes men" phenomenon violates two of the four prerequisites postulated by Surowiecki [17] for collective decision making to perform well: 1) cognitive diversity, by which each individual involved has some private information; and 2) independence, wherein each person's opinion or decision is not influenced by those around them.

The above examples illustrate that while eliciting knowledge from diverse sources may improve decision making [2, 14], it is critically important to examine the incentives of the potential senders of knowledge.

In this paper, we use a game-theoretic approach to study the consequences when a knowledge sender has incentives to transfer knowledge strategically and develop the mechanisms that can be designed to deter such strategic behavior. We find that knowledge transfer may fail when senders transfer knowledge strategically. We propose two mechanisms to induce truthful reporting of knowledge: 1) probabilistic auditing by the knowledge receiver; and 2) probabilistic auditing by the knowledge receiver combined with the receiver's independent knowledge acquisition. We emphasize the importance of auditing in knowledge transfer and show that auditing is necessary to induce truthful knowledge transfer. Further, the knowledge receiver's own knowledge acquisition effort can be combined with probabilistic auditing to facilitate truthful and efficient knowledge transfer, benefiting both the sender and the receiver. Probabilistic auditing has been proposed in capital budgeting processes where managers may be audited when they request for a budget exceeding the capital spending limit [9]. This approach can also be used in investment decision [16]. We apply an auditing mechanism to knowledge transfer, which is a different context from what has been studied before. We also note that in the information management literature the term "information audit" refers to the identification, costing, development and rationalization of information resources and services [5]. Further, the results of an information audit can be used to make clear the contribution made by information and information services to the decision making and performance of an organization [5]. However, the extant literature ignores the examination of the incentives of information sources in an information audit. While the auditing mechanisms we propose in this paper is intended for knowledge transfer, they can also be incorporated into the broader framework of corporate information audit.

We also study the "yes men" phenomenon in knowledge transfer, and show that if a knowledge sender observes the receiver's own knowledge, the sender may behave as a "yes man", which significantly lowers the value of the receiver's own knowledge.

Our research contributes to several strands of literature. First, this paper builds on the sender-receiver framework of knowledge transfer [13] and deepens our understanding of the incentive dimension of knowledge management [1]. Recent empirical research shows that both motivational factors and the recipient's knowledge endowment strongly influence knowledge transfer in complex situations [11]. This paper is related to Lin et. al. [13], but the key difference is that in Lin et al. [13], the knowledge itself has no implications for the senders, while in this paper, the knowledge being transferred concerns the receiver's actions that have repercussions for the sender, therefore knowledge is no longer neutral from the sender's point of view.

Second, this paper emphasizes the role of knowledge receivers in knowledge transfer, which has long been recognized in the knowledge management literature, especially in the absorptive capacity theory. The absorptive capacity theory developed by Cohen and Levinthal [4] suggests that the receiver's prior knowledge facilitates her assimilation of new knowledge. There has since been empirical evidence showing that characteristics of receivers, especially their absorptive capacity, influence the outcome of knowledge transfer [18]. We provide a new rationale for the receiver to acquire knowledge: we find that the receiver's knowledge not only moderates his/her own assimilation of knowledge, it also has an impact on the sender: it induces truthful knowledge transfer and deters the sender's strategic behavior.

Third, this research is related to economic theories for communications between parties with misaligned incentives (e.g., [12, 15]). We contribute to the literature by introducing new solution mechanisms such as probabilistic auditing to deter distorted communication. In addition, the "yes men" problem is exogenous in Prendergast [15] (it assumes that R rewards S for being a yes-man) while it is endogenous in our model as a result of knowledge leaking.

Last but not least, our research contributes to the growing literature on the use of Enterprise 2.0 technologies for knowledge management and decision making [2, 14]. Our results have implications for developing a social media strategy for companies.

2. Base Model

A knowledge receiver (R, she) faces the choice between two options: 1 and 2. Let a denote R's actual choice. One of the two options is the "right" choice, in that this choice eventually leads to a benefit of $v_r + \delta_r$ for R, while the other option, or the "wrong" choice, will lead to a benefit of v_r. Normalize $v_r = 0$, and assume $\delta_r > 0$. *Ex ante*, R does not know which option is the right choice. Let A denote the (unknown) right choice. Thus, *ex ante* R's belief is: $\Pr(A=1) = \Pr(A=2) = 1/2$.

R needs knowledge about these options to improve the likelihood of making the right choice. One approach is that R seeks knowledge from a party who possesses the relevant knowledge, and requests a knowledge transfer. The party who transfers knowledge is the knowledge sender (S, he). Alternatively, R can gain knowledge by exerting effort.

2.1 Two approaches of knowledge acquisition

We first model the knowledge transfer process. A knowledge sender (S) possesses knowledge about the options 1 and 2. Although S's knowledge might be rich and complex, overall it suggests either Option 1 or 2 be the right choice for R (i.e., leading to a higher payoff for R). We use a variable k to represent S's knowledge: k = 1 if S's knowledge identifies Option 1 as the right choice, in which case we say S's knowledge supports Option 1. The option supported by S's knowledge has a probability of at least 0.5 for being the right choice: when k = 1, $\Pr(A=1 \mid k=1) = 1/2 + \theta$, where $0 \le \theta \le 1/2$. Similarly, $\Pr(A=2 \mid k=2) = 1/2 + \theta$. The parameter θ reflects the predictive power, or the quality of S's knowledge: the higher θ, the more likely S's knowledge supports the right choice. Note that we assume that either the sender's knowledge does not improve R's prior belief (in the case of $\theta = 0$), or the sender is more likely to be right than wrong (in the case of $\theta > 0$).

S's knowledge is private to S; in other words, R does not know *which option* S's knowledge supports. Thus, from R's perspective, *ex ante*, $\Pr(k=1) = \Pr(k=2) = 1/2$. However, we assume that R knows the quality of S's knowledge θ. This is equivalent to the assumption that R's expectation of θ equals to its true value. Even though R does not know what S thinks about the two options at question, she can still form an expectation of the quality of S's knowledge based on S's credentials and reputation or through her past interactions with S.

The knowledge that S transfers may again be rich and complex. For example, the knowledge transferred may be codified knowledge in the form of documents, presentations, or reports. But ultimately, it can be summarized as supporting one of the options. Similar to the notation k representing S's knowledge, we use m to represent the knowledge transferred from S to R. Note that the transferred knowledge, which we also refer to as the message, may not be the same as the actual knowledge that S possesses. We say $m = 1$ if the message supports Option 1; S transfers his knowledge truthfully if $m = k$ (i.e., S sends a message consistent with his knowledge), and S misreports his knowledge if $m \ne k$.

R pays S the amount of p for the transferred knowledge. Hereafter we refer to p as the *price of transferred knowledge* (or simply the *price*), or *the compensation for knowledge transfer*.

Therefore, if S transfers his knowledge truthfully and R makes her decision based on the message received, R's expected payoff, denoted by V (we omit the letter "E" to simplify the notation, but it should be kept in mind that the payoffs are expected values), is given by $(1/2+\theta)\delta_r - p$; if S misreports and R follows the distorted message, then $V = (1/2-\theta)\delta_r - p$.

S's incentives may not be perfectly aligned with that of R's; in other words, the decision that is in the best interests of R may not be so for S. S may prefer one action by R than another, and he may transfer his knowledge strategically so that R may make a decision that he prefers. We consider the following three components of S's payoff: 1) the compensation S receives from R; 2) the extra benefit if R chooses the option S prefers; and 3) S's cost of transferring knowledge. To focus on S's bias toward R's decision, we normalize S's cost of transferring knowledge to 0. [1] Without loss of generality, we assume that Option 1 leads to a higher payoff for S than Option 2 (recall that either Option 1 or 2 can be the right decision for R). After S transfers knowledge to R, if R chooses $a=2$, S's payoff is the compensation he receives from R, p; if R chooses $a=1$, S's payoff is $p+\delta_s$, where $\delta_s>0$, representing S's bias toward option 1. The value of δ_s is known to both R and S. Note that knowing the sender's bias δ_s may entail extensive information about the sender, such as his clients, suppliers, competitors, alliances, strategic plans, etc.

If S does not engage in the knowledge transfer, he can earn a payoff of u_s from alternative activities. We assume that R makes a take-it-or-leave-it (TIOLI) offer to S and S accepts if his expected payoff is higher than his reservation payoff, u_s.

Next, we consider R's alternative to seeking knowledge from S: R may acquire her own knowledge k_r by exerting effort e. Similar to S's knowledge, R's knowledge supports either Option 1 or 2. Let $k_r=1$ if R's knowledge supports Option 1 and $k_r=2$ otherwise. The higher R's effort level, the higher the quality of the knowledge she acquires. Therefore, we use the effort level e to represent the quality of R's knowledge: $\Pr(A=1\mid k_r=1)=\Pr(A=2\mid k_r=2)=1/2+e$, where $0\le e\le 1/2$. If k_r is R's sole source of knowledge, R is assumed to choose Option 1 if $k_r=1$ and Option 2 otherwise.

R incurs a cost by exerting efforts. Note that R's effort may take the form of learning from codified knowledge, conducting independent research, or even having knowledge transferred from a third party.[2] The marginal cost of effort, denoted by $c(e)$, is a function of the effort level. Let $c(0)=0$, and $c(e)$ be strictly increasing for $0\le e\le 1/2$. This means that the higher the quality of the knowledge R has acquired, the more difficult it is for her to improve the quality. Let $C(e)=\int_0^e c(e)\,dx$ denote the total (cumulative) cost of effort e for the receiver. The following lemma shows the outcome of R's knowledge acquisition effort.

Lemma 1: *When R acquires knowledge by exerting effort, the optimal level of effort is e^*, which satisfies $c(e^*)=\delta_r$. R's maximized payoff from her own effort, denoted by V_e^*, is given by: $V_e^*=\left(\frac{1}{2}+e^*\right)\delta_r-C(e^*)$.* (All proofs omitted)

We are interested in the case where, barring incentive issues, knowledge transfer is more efficient than knowledge acquisition through R's effort. Therefore, we assume that k_r acquired through the optimal level of effort has lower quality than k, that is, $\theta>e^*$, or $c(\theta)>\delta_r$.

If R neither seeks knowledge nor exerts effort, R will randomly pick an option, realizing an expected payoff of $\frac{1}{2}\delta_r$. To focus on the value of knowledge, we make the following assumption.

Assumption 1: *We assume that $e^*\delta_r-C(e^*)>0$.* In other words, *R receives a higher payoff acquiring knowledge by exerting effort than not.*

2.2 Benchmark case: Non-strategic sender

Before we introduce S's strategic behavior, as a benchmark we first discuss the case of a non-strategic sender, where he always truthfully reports his knowledge. R decides whether to seek knowledge from S or exert effort. She solves the following optimization problem when choosing knowledge transfer:

$$\max_p \; V=\left(\tfrac{1}{2}+\theta\right)\delta_r-p$$

s.t. (1) $p\ge u_s$ (S's IR constraint)

(2) $\left(\frac{1}{2}+\theta\right)\delta_r-p\ge V_e^*$ (R's IR constraint)

Solving the above problem, we obtain the following.

Proposition 1: *Suppose S always truthfully reports. If $p_m\equiv(\theta-e^*)\delta_r+C(e^*)<u_s$, where e^* is R's optimal level of effort in absence of knowledge transfer, R's optimal strategy is to exert effort, and her maximized payoff is V_e^*. If $p_m>u_s$, R's optimal strategy is to choose knowledge transfer, charging an optimal price of $p^*=u_s$. R's maximized payoff from knowledge transfer is given by $\left(\frac{1}{2}+\theta\right)\delta_r-u_s$.*

This proposition shows how the receiver chooses between knowledge transfer and her own knowledge acquisition effort in the case of a non-strategic sender. The result can be illustrated as R's optimal strategy for different values of u_s and p_m: R chooses knowledge

[1] This implies that S's cost of transferring knowledge is the same for both options 1 and 2, regardless of truthful transfer or not. The extra cost of untruthful transfer is reflected in the negative payoff if such behavior is discovered. See Section 3.

[2] In practice, knowledge transferred from a third party may suffer the same issues with knowledge transferred from S, as discussed later in this paper. Our model discusses the cost of knowledge transfer, and the cost of transfer from the third party can then be compared with the cost of transfer from the original sender.

transfer when $p_m > u_s$, and makes her own effort otherwise (see Figure 1).

We also note that when S always transfers truthfully in knowledge transfer, R's optimal price is simply S's reservation payoff, $p^* = u_s$.

This result also suggests that p_m is the maximum price that R is willing to pay for S's knowledge: as S's reservation payoff increases, R will keep increasing the price, but if $u_s > p_m$, R will no longer choose knowledge transfer. The maximum price p_m equals to the sum of the cost of her own effort $C\left(e^*\right)$ and a premium for the sender's higher quality knowledge, $\left(\theta - e^*\right)\delta_r$. Using p_m, R's maximized payoff from her own knowledge acquisition by effort $V_e^* = \left(\frac{1}{2} + e^*\right)\delta_r - C\left(e^*\right)$ can be written as $V_e^* = \left(\frac{1}{2} + \theta\right)\delta_r - p_m$. Therefore, p_m is a measure of R's payoff from her own effort, the alternative strategy other than knowledge transfer.

Will R choose **both** knowledge transfer and her own knowledge acquisition effort? The answer is "no." Suppose R both seeks knowledge from S and exerts her own effort. Since R is making a binary decision between two options, R will simply choose the option supported by the knowledge of higher quality. Thus R's maximization problem becomes:

$$\max_{p,\,e}\ V = \left(\tfrac{1}{2} + \max\left(\theta, e\right)\right)\delta_r - p - C\left(e\right)$$

s. t.: $p \geq u_s$.

Clearly, when R does seek knowledge from S, it is optimal for R not to exert effort at all, $e^* = 0$. In other words, R chooses either knowledge transfer or exerting effort, but not both.

3. Sender's strategic behavior and receiver's solution mechanisms

Since the sender's interests are not aligned with the receiver's, the sender has an incentive to transfer his knowledge strategically, which means he may misrepresent his knowledge to his own advantage. If the receiver does not implement any mechanism to encourage the sender to report his knowledge truthfully (i.e., to deter strategic behavior), no meaningful knowledge will be transferred, as shown in the following proposition.

Proposition 2: *With $\delta_s > 0$ (i.e., S is biased toward option 1), in the absence of any mechanism that verifies the knowledge to be transferred, a request for knowledge results in S reporting $m = 1$, which R always ignores. Therefore, knowledge transfer fails.*

To ensure that S transfer his knowledge truthfully, R needs to design and implement mechanisms that reward truthful transfer and/or punish distorted transfer. We discuss two mechanisms: 1) probabilistic auditing; and 2) R's knowledge acquisition (KA) effort combined with probabilistic auditing. Our analysis involves game theory and the equilibrium concept used is the Perfect Bayesian Equilibrium (PBE) [7].

3.1 Probabilistic auditing by the receiver

The first mechanism we introduce is probabilistic auditing by the receiver, which works as follows. Prior to the knowledge transfer, R announces the following scheme: if S reports $m = j$ ($j = 1, 2$), R will audit S's report with a probability of q_j. Auditing involves investigating (or employing an agent to investigate) whether the sender's report is consistent with his knowledge. Note that for this mechanism to work, the announced scheme must be credible to the sender; in other words, the receiver must demonstrate that she is fully committed to the auditing plan. For example, R can commit to the announced plan by prepaying the expected costs of auditing, such as signing a contract and prepaying a fee. Assume that an audit can always uncover whether the report is truthful or not.[3] Auditing costs the receiver the amount of D. If S is found misreporting, he will get a payoff of $-F$ where $F \geq 0$, regardless of R's choice, which means he will not be compensated, lose the extra benefit δ_s even if R chooses Option 1, and suffer a further loss on top of these.[4]

When R audits S's report, since the audit will uncover whether S has misreported, revealing S's true knowledge (that is true because there are only two options), R chooses the option supported by S's true knowledge, which means $a = k$. When R does not audit, she makes her decision based on the reported knowledge, which means $a = m$.

When $k = 1$, truthfully reporting ($m = 1$) will yield $p + \delta_s$ for S, regardless of the auditing probability q_1 set by R. If S misreports ($m = 2$), since R audits with a probability of q_2, S's expected payoff is given by $\left(1 - q_2\right)p - q_2 F$, which is clearly lower than $p + \delta_s$.

[3] Although it is more realistic to assume that an audit finds out with a probability whether S's report is consistent with his knowledge, our assumption (assuming the probability equals to 1) does not change the results qualitatively.

[4] The further loss for S may be in the form of reputation damage, litigation costs, etc. If the only punishment for being found misreporting is the loss of compensation (and δ_s as well in the case of $a = 1$), then $F = 0$.

Thus, when $k=1$ or S's knowledge supports Option 1, there is no incentive for S to misreport. This also implies that when $m=2$, it must be the case that $k=2$, because S will never report $m=2$ when $k=1$. Therefore, R does not need to audit S's report if $m=2$. In other words, in equilibrium, $q_2=0$. Intuitively, when S sends a message to support an action that he least prefers, it must be a truthful report and thus R does not need to audit such a report.

When $k=2$, S gets p if he reports truthfully ($m=2$); if he misreports ($m=1$), his expected payoff is $(1-q_1)(p+\delta_s)-q_1F$. S will transfer truthfully if and only if $p \ge (1-q_1)(p+\delta_s)-q_1F$. Therefore, S may have incentives to report $m=1$ when his true knowledge is $k=2$. From R's perspective, when she receives $m=1$, it can be either a truthful report (i.e., $k=1$) or a distorted report (i.e., $k=2$). Thus R should set a probability q_1 to audit a report that supports Option 1, the option that S prefers.

From our analysis above we know that S transfers his knowledge truthfully when $k=1$. When $k=2$, the price should satisfy: $p \ge (1-q_1)(p+\delta_s)-q_1F$ for S to transfer truthfully. Overall, in a separating equilibrium where R chooses to seek knowledge from S and S truthfully reports, R solves the following optimization problem:

$$\max_{p,\,q_1} V=\left(\tfrac{1}{2}+\theta\right)\delta_r - p - \tfrac{1}{2}q_1 D$$

s.t.

(1) $p \ge (1-q_1)(p+\delta_s)-q_1F$ (S's IC constraint)

(2) $p \ge u_s$ (S's IR constraint)

(3) $\left(\tfrac{1}{2}+\theta\right)\delta_r - p - \tfrac{1}{2}q_1 D \ge V_e^*$ (R's IR constraint)

Solving the above problem, we obtain the following results.

Proposition 3: *In a separating equilibrium where S truthfully reports:*

1) If $u_s < \frac{\sqrt{2D\delta_s}}{2} - (\delta_s + F)$, *R's optimal strategy is to exert effort when* $p_m < \sqrt{2D\delta_s} - \delta_s - F$, *and to seek knowledge from S when* $p_m > \sqrt{2D\delta_s} - \delta_s - F$, *charging an optimal price given by* $p^* = \frac{\sqrt{2D\delta_s}}{2} - (\delta_s + F)$ *and auditing with probability* $q_1^* = \frac{\sqrt{2D\delta_s}}{D}$. *R's maximized payoff from knowledge transfer is given by:*

$$V^* = \left(\tfrac{1}{2}+\theta\right)\delta_r + \delta_s + F - \sqrt{2D\delta_s}.$$

2) If $u_s > \frac{\sqrt{2D\delta_s}}{2} - (\delta_s + F)$, *R's optimal strategy is to exert effort when* $p_m < u_s + \frac{D\delta_s}{2(\delta_s + u_s + F)}$, *and to seek knowledge from S when* $p_m > u_s + \frac{D\delta_s}{2(\delta_s + u_s + F)}$, *charging an optimal price of* $p^* = u_s$ *and auditing with probability* $q_1^* = \frac{\delta_s}{\delta_s + u_s + F}$. *R's maximized payoff from knowledge transfer is given by:*

$$V^* = \left(\tfrac{1}{2}+\theta\right)\delta_r - u_s - \frac{D\delta_s}{2(\delta_s + u_s + F)}.$$

Proposition 3 describes the receiver's optimal strategies in the case of a strategic sender. We again plot R's strategies for different values of u_s and p_m (see Figure 2). Comparing to the regimes shown in Figure 1, we first notice that with S's strategic behavior, the region where R chooses to exert effort is enlarged, which means the conditions for knowledge transfer are stricter. Furthermore, the region where R chooses knowledge transfer is divided into two regimes, which are called KT1 and KT2 respectively.

In KT1, S's IC binding, and S's IR not binding. Because $q_1^* = \frac{\sqrt{2D\delta_s}}{D}$ is a probability, it must be true that $\delta_s \le \frac{D}{2}$. In KT2, both S's IC and IR are binding. It can be proved that R's payoff in KT1 is always higher than that in KT2. It is easy to understand: in KT2, R has to pay S the price he demands, which is higher than R's voluntary price. If S's reservation payoff is low, R charges a price *higher* than what S demands. If S's reservation payoff is high, R has to pay S his reservation payoff, leading to lower payoff for R.

One of the conditions for KT1 to occur, $u_s < \frac{\sqrt{2D\delta_s}}{2} - (\delta_s + F)$, can be rewritten as a condition on δ_s:

$$\delta_s \ge \tfrac{1}{4}\left(D - \sqrt{D^2 - 8D(u_s+F)}\right) - u_s - F, \text{ and}$$

$$\delta_s \le \tfrac{1}{4}\left(D + \sqrt{D^2 - 8D(u_s+F)}\right) - u_s - F.$$

Basically, δ_s cannot be too high. This is because if δ_s is too high, the voluntary optimal price R is willing to pay is too low, and therefore it is KT2 rather than KT1.

Due to the sender's strategic behavior, knowledge transfer is possible only if the value of S's knowledge to R (p_m) is sufficiently high or the cost of auditing reasonably low. This has interesting managerial implications. For example, when an expert has too much to gain from a particular course of action, even if his knowledge is valuable, it is impossible to use probabilistic auditing to induce truthful knowledge from him.

Proposition 3 shows that S's strategic behavior affects knowledge transfer adversely not only by lowering R's expected payoff, but also by narrowing the range of price for knowledge transfer. Using the probabilistic auditing mechanism, the maximum amount R is willing to pay for S's knowledge is $\frac{1}{2}\left[\left(p_m-\delta_s-F\right)+\sqrt{\left(p_m+\delta_s+F\right)^2-2\delta_s D}\right]$, which is clearly lower than p_m. This is again due to the additional auditing costs.

3.2 Receiver's knowledge acquisition effort combined with probabilistic auditing

One observation that holds true to this point in our analysis is that R will either resort to knowledge transfer or exert effort to acquire knowledge, *but not both at the same time*. Intuitively, for a binary decision problem as modeled in our paper, and if R is able to obtain knowledge from two venues, R's final decision is driven by the more informative piece of knowledge of the two. In other words, the less informative piece of knowledge contributes no additional direct value for R's decision process.[5] In this section we show that even if R's knowledge acquisition (KA) effort does not provide direct information value for R's decision process, it can still be of critical importance for R because of its (indirect) value in enabling a more effective incentive mechanism than the one we discussed in the previous section.

This mechanism combines R's KA effort and probabilistic auditing: prior to knowledge transfer, R announces and commits to that, if S reports $m=i$ and R's own knowledge is $k_r=j$ ($i,j=1,2$), with probability q_{ij} R will employ auditing.

The next proposition shows the equilibrium when self-knowledge acquisition and probabilistic auditing can be adopted simultaneously. For ease of exposition, denote $\tilde{\lambda}_r$ as the solution to

$$c_r(\tilde{\lambda}_r)=\frac{\theta D}{(1/2+2\theta\tilde{\lambda}_r)^2}\bullet\frac{\delta_s}{p+\delta_s}.$$

Proposition 4: *(1) If*

$$(p_m-C_r(\tilde{\lambda}_r)+\delta_s)^2\geq 2\delta_s D\frac{1/2-2\theta\tilde{\lambda}_r}{1/2+2\theta\tilde{\lambda}_r}\ \text{and}$$

$$\max\{\frac{p_m-\delta_s-C_r(\tilde{\lambda}_r)-\sqrt{(p_m-C_r(\tilde{\lambda}_r)+\delta_s)^2-2\delta_s D\frac{1/2-2\theta\tilde{\lambda}_r}{1/2+2\theta\tilde{\lambda}_r}}}{2},0\}$$

$$\leq p\leq\frac{p_m-\delta_s-C_r(\tilde{\lambda}_r)+\sqrt{(p_m-C_r(\tilde{\lambda}_r)+\delta_s)^2-2\delta_s D\frac{1/2-2\theta\tilde{\lambda}_r}{1/2+2\theta\tilde{\lambda}_r}}}{2}$$

, R chooses knowledge transfer. Furthermore, R exerts effort $\tilde{\lambda}_r$ *to acquire knowledge. If S reports* $m=1$ *and R observes* $k_r=2$*, R audits S with probability* $\delta_s/((p+\delta_s)(1/2+2\theta\tilde{\lambda}_r))$*. S truthfully reports and R gets a payoff of*

$$v_r-\delta_r(1/2-\theta)-\frac{D}{2}\bullet\frac{1/2-2\theta\tilde{\lambda}_r}{1/2+2\theta\tilde{\lambda}_r}\bullet\frac{\delta_s}{p+\delta_s}-C_r(\tilde{\lambda}_r)-p$$

(2) Otherwise, R chooses to exert effort λ_r^* *and gets a payoff* $v_r-\delta_r(1/2-\lambda_r^*)-C_r(\lambda_r^*)$.

Proposition 4 shows that KA effort can be an effective component in the mechanism to induce truthfully knowledge transfer. A key feature of audit probabilistic with KA effort is the selective use of auditing: auditing may be used only if the receiver observes a signal that *contradicts* what the sender reports. KA helps R to better decide *when* to use auditing: unlike under auditing-only where audit is used with a positive probability when the sender reports $m=1$, now R audits only if S reports $m=1$ *and* R observes a *contradictory signal* by herself. Intuitively, if S reports $m=1$ and R's own knowledge also suggests $k_r=1$, then $m=1$ is less suspicious. The other side of the story is that when $m=1$ while $k_r=2$, it is much more likely that S is misreporting.

The following corollary summarizes the benefits R receives by adding KA effort into the mechanism:

Corollary 1: *Compared with probabilistic auditing only, probabilistic auditing combined with KA efforts benefits knowledge transfer in two dimensions:*

a) *R receives a higher payoff; and*
b) *R benefits from knowledge transfer in a wider range of cases.*

[5] For a decision problem that is continuous rather than discreet, the less informative piece of information can contribute directly to R's final decision.

4. Knowledge leaking: the "Yes men" problem and solution mechanisms

We have studied challenges of knowledge transfer where knowledge flows from S to R. In practice, nevertheless, knowledge transfer is a highly interactive process and it is not rare that knowledge also flows from R to S, which we call knowledge leaking.

This section studies the impact of knowledge leaking on the effectiveness of the proposed mechanisms. It might appear intuitive to many that the more knowledge sharing, the better for decision making. We show in this section that this is not true: *knowledge leaking can lead to worse results for decision making*.

Suppose knowledge leaking happens with probability β, in which case S can observe R's knowledge learned through KA effort, k_r. β is common knowledge (i.e., both R and S are aware of the possibility of reverse knowledge transfer) and $0 \le \beta \le 1$. $\beta = 0$ is the case without knowledge leaking (studied in our earlier analysis), and $\beta = 1$ is the case where knowledge leaking always happens.

When knowledge leaking happens, S adopts a "yes men" strategy as described in the next proposition.

Proposition 5: *Suppose R adopts probabilistic auditing with KA effort as shown in Proposition 4. If knowledge leaking happens and if $k = 2$, S always reports to R a message consistent with k_r.*

Proposition 5 shows that, under the mechanism proposed in the previous section, if knowledge leaking occurs and when $k = 2$, instead of always truthfully reporting, S will now tailor his report to echo what he believes R already knows. In other words, S behaves as a yes-man.

Note that this "yes men" behavior is not at odds with our discussion in Section 3 that S attempts to manipulate R's opinion barring a proper incentive structure: in Section 4 and under knowledge leaking, S can still mislead R when $k = 2$ and $k_r = 1$.

Also note that in Proposition 4, to guarantee truthful knowledge transfer, it is sufficient (and efficient) for R to audit S with probability only when S's message and R's own knowledge *contradict each other*. When R's knowledge leaks to S, however, S can behave as a yes-man to avoid such conflicting signals and subsequently avoid being audited. As shown below, the possibility of knowledge leaking can significantly reduce the value of R's KA effort in ensuring truthful knowledge transfer.

Proposition 6: *There exists a threshold $\hat{\beta}$ such that:*

a) *if $\beta < \hat{\beta}$, probabilistic auditing with knowledge acquisition efforts benefits R more than probabilistic auditing only;*
b) *if $\beta \ge \hat{\beta}$, probabilistic auditing alone benefits R more than probabilistic auditing with knowledge acquisition efforts.*

Corollary 2. *R's knowledge acquisition effort is valuable as an incentive tool only if the possibility of knowledge leaking is low enough (i.e. $\beta < \hat{\beta}$).*

5. Concluding remarks

Our research has implications to firms using Enterprise 2.0 technologies for knowledge transfer and decision making. We show that incentive misalignment has a negative impact on both knowledge acquisition and knowledge transfer. The receiver's knowledge serves as an incentive-altering mechanism. This provides a new rationale for knowledge acquisition in addition to that offered by the absorptive capacity theory.

McAfee [14] suggests that corporate leaders should at first encourage the use of new tools and then refrain from intervening with too heavy a hand. Our results are consistent with this advice and provide formal analysis.

One of the key insights from our research is that decision makers should actively acquire knowledge, but it is critically important not to leak their knowledge to potential knowledge senders. Specifically, the decision makers, who are knowledge receivers in our model, should let the knowledge senders know that they are seeking knowledge, but should not let the senders know *what* they know. This can indeed be challenging with the proliferation of Web 2.0 technologies.

Our results also have implications for outsourcing practice. We show that in-house expertise benefits both the outsourcing company and the supplier.

Our findings also inform the design of information systems. For example, executive support systems (ESS) should not only include information processed and filtered by subordinates, but also provide access to raw information from various sources. And it is critical to control the direction that knowledge flows to avoid the yes men problem.

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Figure 1: First Best Case: S Non-strategic

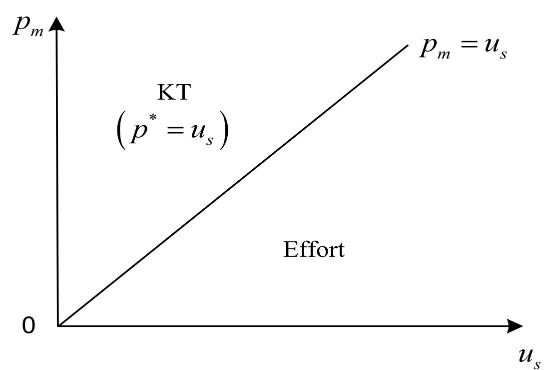

Figure 3: Proposition 3