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Measuring the premium on common knowledge in computer-mediated coordination problems

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ABSTRACT

Common knowledge, whereby everybody knows something, and everybody knows that everybody knows it, and so on ad infinitum, is claimed to be central to coordination in organizations. However, this claim has so far not received empirical support, as a method to empirically compare common knowledge with other forms of knowledge has not been available. In this article, we present a novel method through which we empirically estimate the common knowledge premium—the level of users' preference of common knowledge over "knowledge by all" (where everybody knows something, but not necessarily everybody knows that everybody knows it). Using the method we show that a "premium" of common knowledge over "knowledge by all" does exist consistently, across populations and measuring variations. The findings provide empirical support for the centrality of common knowledge. Implications of the study are discussed.

1. Introduction

Common knowledge (CK) is the subject of research in various disciplines (e.g. Binmore and Brandenburger, 1990; Fagin, Halpern, Moses, & Vardi, 2003). Something is CK if everybody knows it, and everybody knows that everybody knows it, and everybody knows that everybody knows that everybody knows it... and so on *ad infinitum* (Lewis, 1969). This is different from something that everybody knows, but not necessarily everybody knows that everybody knows it, etc. We shall refer to the latter case as "knowledge by all" (KA).

CK is preferable to, or can said to have a premium over KA in coordination situations (Chwe, 2001). Fagin et al. (2003) provide an illustration of this: a society wants all drivers to know that a red light means "stop" and a green light means "go" (this is an example of knowledge by all). However, drivers would feel much safer if they also knew that everybody else knows these rules, and everybody knew that everybody knew them, and so on (this is an example of common knowledge).

CK is seen as key to coordination in organizations: Grant's (1996) Knowledge Based Theory of the Firm, according to which firms exist in order to coordinate the specialized knowledge of their employees, involves CK as underlying such coordination. A similar concept to CK (Carlile, 2004), is that of "mutual knowledge", where parties to a communication share certain knowledge in common and know they share it (Cramton, 2001). In distributed and virtual organizations such mutual knowledge is seen as key to effective communication and collaboration (Alavi & Tiwana, 2002; Cramton, 2001).

However, while the claim of CK importance and its premium in a social or organizational context is used extensively (e.g. Carlile, 2004; Chwe, 2001; Cramton, 2001; Cramton, 2002; McInerney, 2002; Ramasubbu, Krishnan, & Kompalli, 2005), it has not been supported so far by empirical evidence. The CK premium is said to be empirically estimable, at least in principle (Chwe, 2001), but so far no method to do so was presented. In this article, we address this issue.

Being able to support or refute the CK argument has implications for knowledge and coordination research and practice. With the growing trend toward collaborative approach to knowledge management (Awazu & Desouza, 2004; Lutters, 2004; Nov & Rao, 2008; Ong & Lai, 2007), and as new knowledge management systems (KMS) offer different communication channels with varying degrees of reliance on CK (Sabherwal & Becerra-Fernandez, 2005), it is important to know if CK is indeed desirable for coordination, and to what extent.

Thus, in this work we present a method through which we demonstrate the existence of a CK premium in a coordination problem, and estimate its magnitude empirically.

1.1. CK premium estimation

The difference between CK and KA arises in email exchange. Sending an email to an undisclosed list of recipients (using the

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"Bcc" field) establishes KA—all recipients know the content of the email. Conversely, sending an email to a disclosed list of recipients (using the "To" or the "Cc" fields) establishes CK—all recipients know the content of the email, and know that everybody knows it, etc. (Chwe, 2001; Moldoveanu, Baum, & Rowley, 2003).

To illustrate the role of email in establishing CK, let us consider an example of a coordination context that is different from the traffic lights example: when an organization wishes to adopt a unified standard to be used by its members, there is often a need to establish common knowledge of the standard. For example, if an company wants to switch from using the English Imperial System (i.e. inches and feet) to the Metric System in its internal operations, all people in the organization need to know about it, and all people need to know that others know about it and so on and so forth. If management wants to communicate this change via email, it would likely send it using the "To" rather than the "Bcc" field, so that all employees would know that others know about the change, and about other's knowledge of their knowledge of the change.

Building on this distinction, we estimate the CK premium by finding out how preferable sending an email and establishing CK is to sending an email and establishing KA. This can be done by finding out when would a sender of an email be indifferent between sending an email to an undisclosed list of recipients, and sending it to a disclosed list of recipients. This way, we get the sender's perception of the ratio between CK and KA, or the sender's CK premium. Indifference between CK and KA is equivalent to a CK premium of 1; preference of CK over KA implies a CK premium greater than 1; and preference of KA over CK implies a CK premium smaller than 1.

Overall, in what follows we address the following research questions:

1. Test empirically whether, as the theory suggests, people in a coordination situation place a premium on CK.
   Hypothesis: for a coordinator using an email in a quorum situation, the ratio between the number of undisclosed recipients and the equivalent number of disclosed recipients will be greater than 1.
2. In addition to testing for *direction* (i.e. test whether coordinators place a premium on CK), we also want to quantify the *magnitude* of the CK premium (the actual ratio between CK and KA).

2. Methodology

2.1. Procedure

In order to elicit their CK premiums, subjects were asked to coordinate a meeting that requires a quorum of eight people by emailing an invitation to potential participants. The text of the invitation was provided to the subjects by the researchers. The instructions articulated that the potential participants want the meeting to take place, but would not like to waste their time by attending a meeting with no quorum.

Subjects were then asked to state: (1) what would be the minimal number of people in a disclosed recipient list they would email the invitation to, in order to make sure that at least eight people will attend the meeting; and (2) what would be the minimal number of people in an undisclosed recipient list they would email the invitation to, in order to make sure that at least eight people will attend the meeting. The ratio between a subject's answer to questions (1) and (2) constitutes the subject's CK premium. The subjects were not presented with any particular list of recipients, nor were they given any indication as to the size of the pool of potential recipients. The objective of the procedure was only to elicit the *ratio* between the two modes of sending the message, and therefore, no additional information was added.

An alternative estimation method used involved asking subjects what would be the minimal number of people in an undisclosed recipient list that would be equivalent to *a pre-determined anchor*—a number of people in a disclosed recipient list determined by the researchers. Subjects were asked what would be the minimal number of undisclosed recipients that would be equivalent, as far as they were concerned, to ten disclosed recipients, a number slightly higher than the required quorum. Here, too, the ratio between the subjects' replies and the pre-determined anchor constitutes the subject's CK premium.

In order to ensure that the subjects understand their choices, they were asked in the questionnaire to indicate whether they are familiar with using the "To" and "Bcc" fields, and the difference between the fields was explained. Responses from subjects who indicated that they were not familiar with the use of the "Bcc" field were omitted from the data analysis.

In order to establish the validity of the email scenario CK Premium measure discussed above, the procedure outlined by Kerlinger and Lee (2000) was followed, by measuring the correlation of the new measure with another CK measure.

The differences between CK and KA in the context of establishing coordination is illustrated in the CK literature (e.g. Halpern & Moses, 1990; Fagin et al., 2003) through the following *coordinated attack problem*: "Two divisions of an army are camped on two hilltops overlooking a common valley. In the valley awaits the enemy. It is clear that if both divisions attack the enemy simultaneously, they will win the battle; whereas if only one division attacks, it will be defeated. The divisions do not initially have plans for launching an attack on the enemy, and the commanding general of the first division wishes to coordinate a simultaneous attack (at some time the next day). Neither general will decide to attack unless he is sure that the other will attack with him. The generals can only communicate by means of a messenger. Normally, it takes the messenger one hour to get from one encampment to the other. However, it is possible that he will get lost in the dark or, worse yet, be captured by the enemy. Fortunately, on this particular night, everything goes smoothly" (Halpern & Moses, 1990).

Therefore, a study was carried out where subjects' CK/KA ratio was elicited for both the email situation and the coordinated attack situation. The latter was elicited by asking the subjects how likely they thought the attack was going to take place in both cases of CK and of KA, and the ratio between the answers was taken to be the CK premium. Following the procedure recommended by Kerlinger and Lee (2000), a positive and high correlation was expected to exist between the subjects' CK premiums using these two independent measures.

2.2. Data collection

The measure validation survey was administered to 42 graduate students, and the CK premium questionnaire was administered to additional 180 students.

The CK premium questionnaires were administered to 147 graduate students, which were divided to two groups: Subject in Group 1 ($N = 101$) were administered a questionnaire with no pre-determined anchor. Subjects in Group 2 ($N = 46$) were administered a questionnaire with a pre-determined anchor. In addition, another CK premium questionnaire (with no pre-determined anchor) was administered to 33 undergraduate students.

3. Results

The validation survey's email CK Premium mean and correlation with the Coordinated Attack CK Premium are presented in Table 1. As expected, the correlation between the email CK premium measure and the Coordinated Attack CK premium measure was positive, significant and high, which supports the validity of the email scenario CK Premium.

Following the validation survey, the CK Premium survey was administered to three groups (see Table 2). CK premium means and standard deviations elicited in the email scenario are presented in Table 2.

As Table 2 indicates, the hypothesis is supported for all three groups: the mean CK premium was greater than 1 in a statistically significant way in all three groups. The mean CK premium was estimated at 1.53, 2.19 and 2.32 in Groups 1–3, respectively, all of them significantly greater than 1.

A comparison between Group 1 and Group 2 revealed a significant difference between the two ($p < 0.05$). Thus, while both CK premium means were significantly greater than 1, there was a difference between the means of the "anchor" and the "no anchor" samples.

4. Discussion and conclusions

In this paper we use a novel method to quantify and empirically estimate the CK premium in a coordination problem. The results demonstrate the preference of decision makers to CK in a situation that is characterized by a dependency between activities. Moreover, the results support empirically the theoretical CK argument made by Chwe (2001), and lends empirical support to the view of the CK importance in communication and collaboration (Alavi & Tiwana, 2002; Cramton, 2001; McInerney, 2002; Cramton, 2002; Fagin et al., 2003: Carlile, 2004; Ramasubbu et al., 2005). Accordingly, the creation of CK should be encouraged in the design of coordination, communication, and knowledge management systems.

While the CK premium was found to be consistent in its *direction*, its *magnitude* varied across different measurement methods (i.e. anchor vs. no anchor). This may be attributed to a framing effect: subjects' stated preferences change according to the way a problem is framed (e.g. Tversky & Kahneman, 1981). Such framing effect, however, did not influence the *direction* of subjects' CK premium—CK was consistently preferable to KA.

Furthermore, the ratio between CK and KA used in this study is only one way to capture the CK premium. Other possible ways, such as difference between the two could be used. The ratio is used here simply because it neutralizes the need to standardize other measures, or normalize the scales if different numbers of coordinated people are used.

Quantifying the CK premium has also implications for the role of CK in facilitating situations where people want to participate in a group action only if they think others will participate too. Such collective action initiatives, ranging from participation in open source software projects to consumer boycotts, are increasingly coordinated by internet and email communication (Mele, 1999), and can benefit from establishing CK among potential participants. Organizers of such initiatives may be able to quantify the premium of CK in such situations and make informed decisions about the tradeoffs between different communication modes. It should be noted, however, that quantifying the CK premium in an email communication scenario is only possible in settings where there are no privacy restrictions on revealing the addresses of all recipients. In some organizations there may such restrictions, and in such cases mass emails that include the details of recipients cannot be sent.

Future research on CK premium may focus on other organizational situations in which coordination problems arise, such as establishing a standard, or facilitating the creation of network externalities. Alternatively, future research may focus on non-traditional organizational structures, such as distributed and virtual teams, which are an increasingly common method of open source software and other information goods creation (Hertel, Niedner, & Herrmann, 2003; Nov, 2007; Stewart & Gosain, 2006).

Table 1
Validation

	N	Mean	SD	Correlation with coordinated attack CK premium
Email scenario CK premium (no anchor)	42	1.48*	1.42	.42**

Statistical comparison refers to the differences between the sample's CK premium mean and CK Premium = 1 (i.e. where there is no preference to either CK or KA).
* $p < 0.05$.
** $p < 0.01$.

Table 2
CK Premium: Descriptive statistics

Group	N	CK premium Mean	SD
1. Graduate students (no anchor)	101	1.53***	1.15
2. Graduate students–(anchor)	46	2.19***	1.81
3. Undergraduates–(no anchor)	33	2.32**	2.60

Statistical comparison refers to the differences between the sample's CK premium mean and CK Premium = 1 (i.e. where there is no preference to either CK or KA).
** $p < 0.01$.
*** $p < 0.001$.

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