PREDICTION MARKET SYSTEM USAGE AND PERFORMANCE:
AN EXTENSION OF THEORY OF PLANNED BEHAVIOR

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ABSTRACT

Prediction markets have been adopted to forecast events and manage risks related to the events in different projects. This paper scrutinizes the first epidemic prediction markets (EPM) system established in Taiwan, which shows favorable accuracy of the EPM in predicting infectious diseases comparing with expected value of historical data for the same period. It further analyzes the incentive structure as well as system characteristics of prediction markets to attract initial and continuous participation. The paper concludes that public welfare and hedonic motivations are the most significant factors driving members' initial participation in the EPM. Finally, based upon theory of planned behavior, this paper finds that satisfaction and perceived behavior control of participants in the EPM have positive influences on continuance intention and actual participation, while peer influence has little positive impact.

Keywords: technology adoption, epidemic prediction markets, market scoring rules, theory of planned behavior

INTRODUCTION

Prediction market is a forecasting mechanism capable of processing the dynamic aggregation of dispersed information from various participants (Forsythe et al., 1992). By definition, a prediction market is a market where the participants are allowed to trade "future event contracts" based on their judgment of contract price trends as well as event result predictions. Contract prices may be used as references to evaluate the chances of occurring of specific events, as well as how they will occur. In the recent two decades, prediction markets have been proven empirically to be remarkably accurate in forecasting future events (Wolfers & Zitzewitz, 2006; Manski, 2006). Prediction markets have two major characteristics which are advantageous in prediction accuracy over traditional methods of prediction. First is the

incentive structure of reward and punishment, which induces participants to provide real and effective information. Second is the continuous update of information for the predicted events. Traditionally, expert deliberations or surveys could be conducted from time to time, yet it is impossible to provide continuously-updated information and reach consensus constantly. In contrast, by prediction markets, participants conduct trade online to provide real-time information. As a result, prediction markets have been adopted recently as a research method to forecast events (or trends) and manage risks related to the events in different projects, institutions, societies, or countries. Nevertheless, very few papers have discussed what characteristics make a prediction market system effective, what basic elements and quality of a prediction market system motivate participants to actively trade in the prediction markets, what drives participants to continue prediction market usage. These questions are particularly important for improving the system and attract more participants to prediction markets.

LITERATURE REVIEW

Prediction Markets

In terms of decision-making, Berg and Rietz (2003) and Sprenger, Bolster, and Venkateswaran (2007) argue that prediction markets with expectations about the likelihood of events conditional on other events occurring could be used for decision support and provide a more effective mechanism for aggregating information than group deliberations. Hahn and Tetlock (2005) concur that prediction markets can be an efficient way to implement well-informed policy decision. In terms of health policy risks management, Polgreen, Nelson, and Neumann (2006, 2007) establish the first prediction market for tracking and forecasting emerging infectious diseases, such as severe respiratory syndrome and avian influenza. Originally, the market was called Iowa Influenza Market; it was re-named to Iowa Health Prediction Market (http://fluprediction.uiowa.edu). Data from a pilot study in the state of Iowa suggest that these markets can accurately predict statewide seasonal influenza activities 2-4 weeks in advance. Despite the outstanding performance of the prediction markets, Polgreen, Nelson, and Neumann (2007) briefly elaborate the system design of the prediction markets without further examination of system features or different scenarios of system designs. Obviously, prediction markets have a good record of prediction accuracy and have been applied to many areas, either public or private domain. But few papers have analyzed how to design an effective system of prediction markets with an appropriate incentive structure for participants. If a system of prediction markets could not attract sufficient participants to engage trading in the market, it is in vain to appraise the predictive power of prediction markets. Therefore, the following sections will introduce the hypothesis according to the related theories in the information systems (IS) field.

The Relationship of Quality and Satisfaction

According to Seddon (1997) and DeLone and McLean (1992, 2003) models in the IS field, user satisfaction as impacted by beliefs about the IS quality, including the service quality, information quality and system quality. These relationships are consistent with Theory of Planned Behavior (TPB) (Ajzen, 1991) where attitude about using the system are impacted by beliefs about the system. Prior studies in the marketing and IS fields also reveal that service quality, information quality, and system quality after actual system use are the antecedents of overall customers/users satisfaction (Spreng et al., 1996; Cronin et al., 2000; Hellier et al., 2003; Lewis and Soureli, 2006). Thus, we hypothesize:

> *H1a: Service quality has a positive influence on satisfaction.*
> *H1b: Information quality has a positive influence on satisfaction.*
> *H1c: System quality has a positive influence on satisfaction.*

The Relationship of Satisfaction and Intention

DeLone and McLean (1992) indicated that "successful interaction by management with the information system can be measured in terms of use satisfaction" and that "user satisfaction as (a success measure is) especially appropriate when a specific information system was involved" (p.68). Satisfaction toward the information and system quality represents "object-based attitudes that serve as external variables shaping behavioral beliefs" (Wixom & Todd, 2005). In other words, level of satisfaction subsequently may have the influence on beliefs about the consequences of using the object. Researches indicated that overall user satisfaction with the system is strongly associated with the behavioral intention to reuse the same system and can be regarded as a reliable predictor of continuance intention (LaBarbera & Mazursky, 1983; Cronin et al, 2000). Furthermore, other researchers found e-satisfaction exhibits a positive impact on e-loyalty (Anderson & Srinivasan, 2003; Yang & Peterson, 2004). Based on these findings, we hypothesize:

> *H2: Satisfaction has a positive influence on continuance intention.*

The Relationship of Peer Influence and Intention

According to the TPB, subjective norm means "the person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein & Ajzen, 1975, p. 302). It is because people may act based on the perception of what referent others think he or she should or should not do. Prior researches showed that there is a positive relationship between the subjective norm and behavior intention toward the system use (Karahanna et al., 1999; Taylor & Todd, 1995; Kwon & Onwuegbuzie, 2005). In

this research, the users of the EPM system are medical affairs professionals. Their attitude toward the EPM system use may be influenced by the colleagues or friends who are in the same professional field. Therefore, we hypothesize

H3: Subjective norm has a positive influence on continuance intention.

The Relationship of Perceived Behavior Control and Intention

Perceived behavior control (PBC) refers to a person's perception of ability to carry out a behavior with the given resources (Ajzen, 1991). It means that PBC denotes a subjective level of control over the performance of a behavior. Therefore, PBC is the user's perception of control over using the EPM system. The higher the perception that one thinks he or she can have the ability to use the EPM system, the higher the intention the one has toward the EPM system usage. A number of empirical studies show the positive relationship between the perceived behavioral control and use intention (Taylor & Todd, 1995; Pavlou & Fygenson, 2006). Consequently we hypothesize:

H4: Perceived Behavior Control has a positive influence on continuance intention.

The Relationship of Self-Efficacy and Perceived Behavioral Control

Self-efficacy is the belief "in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 1997, p.3). This concept refers to an individual's self-evaluation regarding the effort and persistence put forth when facing with obstacles, and finally, the mastery of the behavior. Such evaluation of individual would influence decisions about what behaviors to undertake. In this study, we consider it as "individual assessment of a person's ability to use the computer and Internet." If a person has a belief that he or she can operate the computer or Internet, it implies that the person is more likely to consider he or she can have the capabilities to use the EPM system. Evidence shows that there is a positive relationship between the self-efficacy and perceived behavior control (Pavlou & Fygenson, 2006; Taylor & Todd, 1995), thus we hypothesize:

H5: Computer self-efficacy has a positive influence on perceived behavior control.

The Relationship of Familiarity and Perceived Behavioral Control

Familiarity stands for an understanding, often based on prior interaction, experience, or learning of what, why, where and when others do what they do (Luhmann, 1988). It deals with the understanding of the current interaction with the objects or people and would reduce the uncertainty about the objects. In our research context, familiarity is based on comprehension of the EPM system due to prior related experience. If a person is familiar with

the EPM, he or she may have the related knowledge about the EPM. It would reduce the uncertainty about the EPM and enforce someone's self-judgment about whether he or she has the ability to use the EPM system. Therefore, we hypothesize:

H6: Familiarity with the EPM has a positive influence on perceived behavior control.

METHODOLOGY

Sample

This paper designed and built the epidemic prediction markets (EPM) system sponsored by the Centers for Disease Control (CDC) of Taiwan. From March to October 2010, 630 medical affairs professionals registered with this market. Members of this EPM system were encouraged to predict three epidemics with five indicators, including severe complicated influenza case, confirmed cases of Dengue fever, confirmed cases of Enteroviruses infection, ratio of Enteroviruses infection cases, and ratio of Influenza-like illness cases.
In total, 630 registered members participated in this system by invitation of CDC and investigators. However, the actual number of traders was 126.

Participants were encouraged to predict the three epidemics with five indicators seven weeks in advance and in seven areas in Taiwan. If every week's prediction is an event sample, there are 7,945 samples in total. Participants with accurate prediction would gain positive credits, and vice versa. Prediction performance was measured by four indicators: cumulative credits, average credits per prediction, number of winning cases and ratio of winning cases among total cases.

Measures

All measurement items were drawn from the extant studies, and a refinement was conducted by two professors, one post-doctor, and one PhD. Student, checking the wording and meaning of each item with corresponding construct. We used the system log to record the history of each user's system usage in the trading period, including the number and the volume of trading in the trading period respectively. Unless the items of system usage retrieved from system log, each item in our questionnaire was measured by a 6-point, Likert-type scale, ranging from 1 (strong disagree) to 6 (strong agree). Indeed, we designed two editions of questionnaire for the different types of participants, including long edition and short edition of questionnaire. Long edition of questionnaire included all items, whereas the short edition included the items of motivation constructs, namely, peer influence, Unitarian, enjoyment, and self-efficacy. More details of survey procedure would be described in the following section.

Survey Procedure

After the trading period, researchers checked the trading records of each member from the EPM system to confirm whether user made the trading in the EPM system. Research questionnaire would be designed to survey two kinds of the participants, one was participants who actual make trades in the trading period and the others were no trading record in the EPM system. By confirming the trading record of each member in the EPM system, there were 126 members actually engaged in trading through the EPM system designed by this research. And 404 members did not make any trading in that period. With the two kinds of questionnaire, long edition of questionnaire were distributed to the 126 participants who actually made trading in the trading period, and remaining was invited to fill out the short edition questionnaire. Members in the EPM system were invited to fill out the questionnaire through click on the Web URL link provided in the invitation email message, which linked to an online survey instrument.

RESULTS

Finally, 126 members actually engaged in trading in this EPM system. Comparing predictions of infectious disease by the EPM and expected value of historical data for the same period, this project finds that the winning ratio for the epidemic market prediction is rising gradually along with approaching target weeks of prediction. Overall, prediction performance of the epidemic prediction markets was excellent. Particularly, the winning ratio for the EPM has been more than 50% for 6 weeks before the target weeks and afterwards.

Out of 126 participants distributed by long edition questionnaire, 51 responses were obtained, 4 were excluded from this research due to excessive missing values, and remaining were 47. Whereas the short edition questionnaire was collected 91 responses, and complete sample was 81. For the data collected from the two types of questionnaire, we compared two kinds of participants with motivations, including the items of peer influence, Unitarian, enjoyment, and self-efficacy. We sets up a dummy variable taking the value with 1 and 0, and the value equals to 1 with the participants who had made trading in the trading period with long edition questionnaire; and the value equals to 0 with the registered member who did not trade. Then, we conducted the T-test to compare means difference within the two groups. All the relationships are significant.

In the next phase, we used partial least square (PLS) to analyze our collected data. PLS employs a component-based approach for estimate purpose (e.g., Lohmoller, 1989). Chin et

al. (2003) indicated that PLS places minimal restrictions on measurement scale, sample size, and residual distributions.

The Measurement Validation and Structural Model

Measure validation was calculated by the internal consistency scores by the composite scores (Werts et al., 1974) which are acceptable since they exceed 0.7. And the methods to validate the convergent and discriminant validation were according to Chin (1998). Results show that all measures have adequate convergent and discriminant validity. Further, we used the PLS to analyze our hypothesis of research model, most of PLS path coefficients are positive significantly, however the impacts of peer influence on continuous and service quality on satisfaction are not significant.

CONCLUSIONS AND IMPLICATIONS

According to the result of the study, the continuance intention has a positive relationship with the degree of participation. As DeLone and McLean (2003) suggest, positive experience with "use" would increase the "user satisfaction", and then "user satisfaction" would increase "the intention to use", then "use." The close-loop relationships between those factors occur specially in the post-use condition. The result of this study supports this evidence. Regarding the quality of EPM system, information quality and system quality are the essential factors that user may pay more attention to. However, in the context of the prediction market, service provided by the website is not an important factor of user's satisfaction. Finally, this research provided an example of prediction market based on the market scoring rules mechanism. With the limited participation in this study (actually 126 participants), this mechanism overcame the obstacle and generated high volume of activities for the prediction market. For the information systems field, this study identified the set of accessible beliefs with the extension of theory of planned behavior, including the system quality, information quality, familiarity, and computer self-efficacy. It could be applied to other prediction applications and other disease trends.

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