ANTECEDENTS OF SOLUTION QUALITY IN CROWDSOURCING: THE SPONSOR'S PERSPECTIVE

Haichao Zheng
School of Economic Information Engineering
Southwestern University of Finance and Economics
555 Liutai Ave., Wenjiang District, Chengdu, China
haichao_zheng@163.com

Zongxiao Xie
Business School
Nankai University
Baidi Road, Nankai District, Tianjin, China
xiezongxiao@vip.163.com

Wenhua Hou
Business School
Nankai University
Baidi Road, Nankai District, Tianjin, China
whhou@nankai.edu.cn

Dahui Li*
Labovitz School of Business and Economics
University of Minnesota Duluth
1049 University Drive, Duluth, MN, USA
dli@d.umn.edu

ABSTRACT

Crowdsourcing has been adopted by firms as a means to access external information, knowledge, and business solutions. How to successfully conduct crowdsourcing is an important question and has drawn significant attention from the research community. The current study developed a research model and tested the model in the case of design contest, using both objective and subjective data collected from a Chinese crowdsourcing platform. We found that both solution quantity and solution diversity had significant effects on solution quality. Further, award had a significant impact on solution quantity but not solution diversity. On the other hand, sponsor-solver interaction significantly increased solution diversity but not solution quantity. Implications are discussed to guide further research and practices in this important area.

Keywords: Crowdsourcing; Solution quality; Solution quantity; Solution diversity; Award; Sponsor-solver interaction

1. Introduction

Realizing the abundance of experts and knowledge distributed outside firm boundaries, firms have started to adopt open innovation strategies to collaborate with external experts, such as lead users, customers, suppliers, universities, and research institutions [Chesbrough 2003; 2006; Howe 2008; von Hippel 2005; Jeppesen and Frederiksen 2006]. Among these approaches, crowdsourcing via the Internet is an effective method to outsource a firm's business tasks to the global crowd to obtain solutions to the tasks [Ebner et al. 2009; Howe 2008; Hagel and Brown 2009; Yang et al. 2009]. Typically, a firm or sponsor organizes crowdsourcing on its own private platform, such as SAPiens initiated by SAP [Leimeister et al. 2009]. A sponsor can also collaborate with a third party (e.g., InnoCentive) that organizes crowdsourcing tasks on a public platform for many sponsors. The crowd or solvers are drawn to the platform and provide solutions to the tasks.

* Corresponding author

How to improve solution quality is an important issue in crowdsourcing [e.g., Girotra et al. 2010; Page 2007; Terwiesch and Ulrich 2009]. To leverage the collective intelligence of the crowd and obtain high-quality solutions, the quantity (number of submitted ideas/solutions) and diversity (variance of the solutions) of submitted solutions by the solvers are considered to be two important precursors [Girotra et al. 2010]. Terwiesch and Ulrich [2009] proposed that quantity and diversity had complementary impacts to improve the quality of the best solutions. The prior research has examined the effect of monetary award in crowdsourcing [e.g., Bullinger and Moeslein 2010]. Award is a significant antecedent for reaching a higher number of solutions (quantity) as well as a variety of solutions (diversity). The sponsor can then invest their effort in choosing an ideal solution from these solutions [e.g., Archak and Sundararajan 2009; DiPalantino and Vojnovic 2009].

Prior literature has also investigated the role of interactions among solvers, between sponsors and intermediaries, and between solvers and intermediaries in the process of crowdsourcing [Adamczyk et al. 2011; Blohm et al. 2010; Bullinger and Moeslein 2010]. However, little research has examined direct interactions between sponsors and solvers as well as the effects of such interactions on the quantity and diversity of solutions. Consistent with Bullinger et al. [2009], which proposed a systematic view for sponsors and solvers to interact in the innovation contest, we posit that sponsor-solver interaction is an effective way to reach ideal solutions.

Such direct interactions eliminate the need for moderation and facilitation of the intermediary or organizer of the platform. The user innovation literature has revealed the importance of co-creation of products and services between a company and its consumers [Algesheimer et al. 2010; Fang et al. 2008; Jeppesen and Frederiksen 2006]. Howe [2008] also suggested that solvers needed directions and guidance from the sponsor or other members who administered the crowdsourcing platform, although these solvers might be capable of self-organizing the crowdsourcing process. Thus, to achieve superior contest performance, the sponsor should not only provide a reasonable award, but also interact with solvers as the contest progresses [Yang et al. 2009]. Contest award and sponsor-solver interactions are signals at different stages of the crowdsourcing process and may have a complementary effect on the outcomes of the contest.

It is also noteworthy that most existing studies are based on secondary data, which are publicly accessible on the crowdsourcing platform [e.g., Bullinger et al. 2009; Ebner et al. 2009; Yang et al. 2009]. There is limited research using subjective data collected from sponsors to investigate their subjective experience. To our knowledge, no studies have analyzed both subjective and objective data about the sponsors. In addition, most studies are based on case studies that include a limited number of observations of the sponsors [e.g., Bullinger et al. 2009; Ebner et al. 2009], rather than large-scale data collection. Bullinger and Moeslein [2010] cautioned about the generalizability of the research findings from these case studies.

In order to address these gaps, this study aims to examine solution quality in crowdsourcing from the sponsor's perspective. Our first research question is: how do award and sponsor-solvers interaction impact solution quantity and solution diversity? The second research question is: how do solution quantity and solution diversity affect solution quality? We have developed a theoretical model and tested the model in the context of design contest which is a type of ideation contest [Terwiesch and Xu 2008]. Both objective data and subjective data were collected from a Chinese crowdsourcing platform. The results show that quality and diversity had complementary impacts on solution quality. Contest awards and sponsor-solver interaction had similar complementary impacts too.

2. Literature Review

2.1. Crowdsourcing

Howe [2006] defined crowdsourcing as "the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call." The functions or jobs outsourced to external entities can be performed by a collaborative group or by individuals [Howe 2008]. Some crowdsourcing practices are designed for high-level competitions among solvers (e.g., InnoCentive), while others are for high-level collaborations among solver community with less competition (e.g., www.hsx.com). This study examines the crowdsourcing with the contest mechanism.

Generally, crowdsourcing contests could be conducted in two different formats. The first is crowdsourcing with no intermediaries. This type of crowdsourcing is conducted on a company's own platform or online community, such as SAPiens, which is an idea competition component of SAP ERP [Leimeister et al. 2009]. Another example is Threadless.com, which builds its own platform to conduct T-shirt design contests [Brabham 2008]. The second type is crowdsourcing with an intermediary. A company or sponsor collaborates with the intermediary, who facilitates and moderates the crowdsourcing process between the sponsor and the solvers. For example, InnoCentive is one of the best-known crowdsourcing intermediaries. Leading commercial, government, and nonprofit organizations such as Procter & Gamble, Solvay, and Avery Dennison have collaborated with InnoCentive to conduct a variety of

contests related to chemistry, computer science, IT, engineering, design, mathematics, and statistics. We study the crowdsourcing contest with an intermediary.

Crowdsourcing contests differ in several dimensions, such as professional knowledge requirement and goal clarification [e.g., Terwiesch and Xu 2008]. Terwiesch and Xu [2008] classified crowdsourcing contests based on market uncertainty and technical uncertainty. Market uncertainty refers to the extent to which the sponsor has no clear goals or tastes. Technical uncertainty means the extent to which the contest task has no clear solution landscape. For tasks with high technical uncertainty, solvers cannot anticipate the performance of a solution before actually conducting the experiment [Terwiesch and Xu 2008]. Ideation contest, expertise-based contest, and trial-and-error contest are three important types of crowdsourcing contest. Ideation contest does not have clear specifications, but its market uncertainty is high. As for expertise-based contest, the sponsor has clear goals, which means that market uncertainty is low [Terwiesch and Xu 2008]. Both ideation contest and expertise-based contest have relatively clear expectations of the solution performance. Thus, their technical uncertainties are low. For trial-and-error contest, solution landscape is extremely rugged, leading to uncertainty in how to improve a solution [Terwiesch and Xu 2008]. Therefore, technical uncertainty of trial-and-error contest is high.

2.2. Sponsor-solver Interaction

As mentioned above, there is limited research regarding the role of sponsor-solver interaction in the crowdsourcing literature. This section reviews the relevant literature to highlight the significance of this concept in crowdsourcing.

Prior literature recognizes that the collaboration within the crowdsourcing community is an attractive motivator for solvers to contribute to problem solving [Antikainen et al. 2010]. Solvers are found to provide comments or peer reviews on other solvers' solutions [e.g., Adamczyk et al. 2011; Antikainen et al. 2010; Ziegler and Hamker 2011]. Ziegler and Hamker [2011] and Hutter et al. [2011] used "collaborative competition" and "communitition" to describe crowdsourcing in which solvers review others' solutions.

Compared with the collaborations among solvers, the interaction between the sponsor and solvers does not gain much attention in the extant research. The main reason may be because crowdsourcing is reviewed as a sequential rather than a synchronous game between the sponsor and solvers [Archak and Sundararajan 2009; DiPalantino and Vojnovic 2009; Terwiesch and Xu 2008]. In a sequential game, there is limited interaction, and the sponsor tends to hide its identity in order to keep the competition secret [Chesbrough 2006]. The platform provider acts as the intermediary to communicate with both the sponsor and solvers [Chesbrough 2006]. For example, InnoCentive staff members provide trainings for the sponsors about how to clearly define crowdsourcing problems. They then disclose crowdsourcing information to solvers as the contest proceeds. Finally, only the winner knows the sponsor's identity. However, active sponsor-solver interactions are observed on other crowdsourcing platforms. Yang et al. [2009] investigated a Chinese crowdsourcing platform, Taskcn.com, where a sponsor could examine a solver's solution and provide feedback on the preferred solutions before the crowdsourcing contest ends. The sponsor could also invite solvers to join the crowdsourcing directly. In addition, a solver could query the sponsor about contest requirements.

Studies of user innovation and consumer virtual communities have found the positive role of firm-consumer interactions [Nambisan 2002; Thomke and von Hippel 2002]. Interactions between a company and consumers in a virtual community are important to increase consumers' participation and efforts [Algesheimer et al. 2010; Fang et al. 2008; Jeppesen and Frederiksen 2006]. Jeppesen and Frederiksen [2006] found that feedback from the sponsor was an important motivator for users to join the virtual community. Even a simple invitation email from the company can significantly increase customer participation in the community [Algesheimer et al. 2010]. Further, information sharing and coordination in interactions with consumers can positively affect new product value, new product initiation, and prototype implementation [Fang et al. 2008; Nambisan 2002; Schreier and Prügl 2008; Thomke and von Hippel 2002]. This stream of literature provides support for the current study to examine the interactions between a sponsor and solvers in crowdsourcing.

3. Research Model and Hypotheses

In this section, we present a research model (Figure 1). The outcome of the model is solution quality, which can be defined as the overall characteristics of the best solution that is able to satisfy the sponsor's desires, expectations, and needs in the crowdsourcing contest [Kotler 2000]. This definition implies that the sponsor is concerned about the winning solution. Although the sponsor can benefit from all solutions in ideation contests and trial-and-error contests, it is optimal to grant the entire award to the best solution [Terwiesch and Xu 2008]. In addition, sponsors are allowed to select the top solution. We posit that the quality of the optimal solution is determined by solution quantity and solution diversity. We then reveal the roles of award and sponsor-solver interaction in the model.

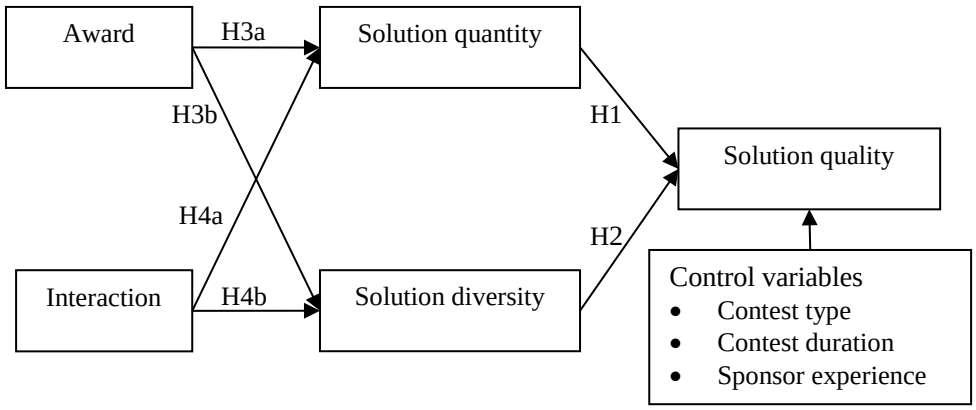


Figure 1: Research Model

3.1. Solution Quantity

Solution quantity refers to the number of solutions submitted by the solvers, from which the sponsor evaluates and chooses the optimal solution at the end of a crowdsourcing contest. DiPalantino and Vojnovic [2009] examined solvers' participation in crowdsourcing, which was measured in terms of solution quantity, as an important benefit for the sponsor.

Through crowdsourcing, the sponsor can get multiple solutions to a crowdsourcing contest, although only one solver or a few solvers can get the award. In the traditional innovation tournament with unobservable research inputs, such as prototype tournaments that were regularly sponsored by U.S. Army Air Corps prior to World War II, the sponsor can control the number of solvers involved in the contest (e.g., several competing manufacturers) [Taylor 1995]. However, sponsors do not have the control over the number of potential solvers in the context of crowdsourcing. Therefore, the sponsor is not able to predict the exact number of solutions before the end of a contest. A higher number of solutions submitted by the solvers may be better off for the sponsor to identify the ideal or satisfactory solution. On the other hand, solvers do not have complete information about the current number of solvers involved in a contest, because all the solvers enter a crowdsourcing contest in a dynamic manner. The number of solvers who participate in a contest and submit solutions is uncertain until the end of the contest [Yang et al. 2009].

Although only the solver who proposes the best solution wins the award, other solutions can also contribute to increase the sponsor's expected payoff [Terwiesch and Xu 2008]. At least, the ultimate success of one solution is not affected by other unsuccessful solutions [Howe 2008]. If a wrong solution does not work for a contest problem, the sponsor can ignore the solution [Howe 2008]. Therefore, encouraging more potential solvers to participate in crowdsourcing is the key to success [Leimeister et al. 2009].

It is noteworthy that solution quantity may have different impacts on solution quality for different contests. For expertise-based contests, solution performance is dependent on a solver's expertise. The most efficient solver will maximize solution performance. In this case, solution quantity does not increase solution quality [Terwiesch and Xu 2008]. However, this study investigates design contest which is one type of ideation contest. The expertise level is identical to all solvers, and the uncertainty of solutions is high [Terwiesch and Xu 2008]. All solvers may exert the same level of effort in such a contest. Therefore, solution quantity will increase the probability of getting an ideal solution. Therefore, we hypothesize:

H1: Solution quantity is positively correlated with solution quality.

3.2. Solution Diversity

Following Terwiesch and Ulrich [2009], we define solution diversity as the uniqueness of the pool of solutions submitted by solvers, i.e., the extent to which solutions are different from each other. Solution diversity is, therefore, different from solution quantity. In our study, we investigate solution diversity rather than solvers' diverse expertise, which is believed to be the power of crowdsourcing [Howe 2008]. Clearly, solution diversity is derived from solvers' diverse expertise and diverse perspectives. Solution diversity is also similar to solution novelty, sometimes referred to as rarity or unusualness, which was proposed by Dean et al. [2006] as one important dimension to evaluate creative ideas.

A random collection of problem solvers outperforms the best individual solver on a difficult problem for which no individual solver can locate the global optimal solution [Hong and Page 2004; Page 2007]. Solvers' collective intelligence is based on their diverse expertise, which can be integrated and processed to solve difficult problems through crowdsourcing [Howe 2008]. Crowdsourcing can attract specialized scientists with diverse interests [Lakhani et al. 2007]. The sponsor can benefit from having more solvers and more diversified solutions [Terwiesch and Xu 2008]. Differences in perspectives and heuristics may be the sources of problem resolution [Jeppesen and Lakhani 2010; Page 2007]. For example, Jeppesen and Lakhani [2010] analyzed 166 scientific crowdsourcing contests in InnoCentive and found that technical and social marginality, which was a source of different perspectives and heuristics, accounted for an individual's success in problem solving.

Although the literature suggests that a sponsor should limit a crowdsourcing contest to two solvers in order to minimize the effort of evaluating solutions [Che and Gale 2003], Terwiesch and Xu [2008] showed that the benefit of diversity could outweigh, or at least mitigate, the negative effect of underinvestment caused by the competition. They proposed that free entry, i.e., no restriction on solvers' entry to crowdsourcing, was optimal for ideation projects and trial-and-error projects, because a free entry policy could draw more solvers and increase solution diversity [Terwiesch and Xu 2008]. Terwiesch and Ulrich [2009] also suggested that the sponsor could benefit from better knowledge and diversity in a diverse pool of solvers.

Howe [2008] argued that collective intelligence diminished when there were too many common characteristics among the solvers. Holding the average solution number constant, Terwiesch and Ulrich [2009] found that increasing solution diversity could generate more solutions that were exceptional for the sponsor. In other words, if the sponsor acquires many solutions of the same style (i.e., low solution diversity), the chance of finding an ideal solution is very small. However, a diverse range of solutions increases the likelihood for the sponsor to get a high-quality solution. Therefore, we hypothesize:

H2: Solution diversity is positively correlated with solution quality.

3.3. Award

Award can motivate solvers to join crowdsourcing contests. Bullinger and Moeslein [2010] reviewed 50 crowdsourcing contests and found that 20 contests were based solely on monetary rewards, while the other 30 contests combined both monetary rewards and non-monetary rewards. Zheng et al. [2011] examined the motivations of solvers in a Chinese crowdsourcing platform and identified non-monetary rewards, such as gaining recognitions (which can be provided through interactions between the sponsor and solvers) as influencing predictors for solver participation.

One stream of research investigated the effect of award from the economic perspective [e.g., Archak and Sundararajan 2009; DiPalantino and Vojnovic 2009], which indicated that monetary reward played a significant role in exploring ideal solutions. The higher the reward, the higher the number of solutions the sponsor receives [DiPalantino and Vojnovic 2009; Terwiesch and Xu 2008]. Crowdsourcing contests with higher rewards are able to attract a larger group of solvers, including those who have the best expertise. In addition, similar findings are reported in an empirical study [Yang et al. 2009], which found that crowdsourcing award had a significant positive effect on the number of solutions submitted by solvers. Therefore, we hypothesize:

H3a: Award is positively correlated with solution quantity.

The motivation literature indicates that a higher money prize can motivate solvers to participate in and exert more effort in crowdsourcing contests. Leimeister et al. [2009] found four important motives: learning, direct compensation (i.e., award incentive), self-marketing, and social motive. Brabham [2010] found similar motives, which included the opportunity to make money, the opportunity to develop one's creative skills, the potential to find job opportunities, and loving the community involved.

The desire to earn an award and other intrinsic motivations, such as enjoying problem-solving, are positively associated with the probability of being a winning solver [Lakhani et al. 2007]. Crowdsourcing award can motivate solvers to exert more effort to create more perspectives and heuristics [Leimeister et al. 2009; Terwiesch and Xu 2008; Yang et al. 2009], which will generate more creative solutions [Page 2007]. Creativity and innovativeness are the key measures of the performance in ideation competitions [Piller and Walcher 2006]. Previous research finds that for ideation contests the sponsor's expected profit or the performance of a contest increases with the solvers' efforts [Terwiesch and Xu 2008]. Therefore, crowdsourcing award increases solution diversity. In addition, a higher award may be more attractive to a broader crowd, where a greater heterogeneity of talents exists. Therefore, we propose

H3b: Award is positively correlated with solution diversity.

3.4. Sponsor-solver Interaction

The interaction between the sponsor and solvers is an important mechanism in crowdsourcing. Lack of interactions can create a negative word-of-mouth message about the sponsor company, because the solvers may

criticize the company for its laziness [Howe 2008]. Sponsor-solver interaction differs between InnoCentive and other crowdsourcing intermediaries, such as www.680.com and www.taskcn.com in China. In InnoCentive, the solvers interact with InnoCentive's staff to receive additional information, rather than directly with the crowdsourcing sponsor [Chesbrough 2006]. In contrast, sponsors in Chinese platforms are able to interact with solvers directly on the public online community, by private email, or through instant messengers. In this context, feedback is often provided by the sponsor to solvers [Yang et al. 2009]. In addition, the sponsor can invite preferred solvers to join a crowdsourcing contest.

In the context of company-driven crowdsourcing where there is no intermediary, the sponsor is seen to be more engaged in the interaction process [Bullinger et al. 2009; Ebner et al. 2009]. Before the start of a crowdsourcing contest, the sponsor invites outsiders (partners from academia) and insiders (partners from industry) to join the crowdsourcing by means of a variety of communication media [Adamczyk et al. 2010]. In addition, the sponsor communicates with solvers in the pre-phase of the crowdsourcing contest. Ebner et al. [2009] described the ideation competition process of SAPiens in terms of five phases: pre-phase, idea generation and revision, community evaluation, expert evaluation, and an idea award ceremony. In the pre-phase stage, the sponsor hosts discussions with experts and selected partners to engage the stakeholders and solvers and to clarify the stakeholders' expectations and concerns [Ebner et al. 2009]. Similarly, Bullinger et al. [2009] also conceived five phases: preparation, communication, execution, evaluation, and follow-up. At the communication stage, the sponsor tries to create an awareness of the crowdsourcing contest and involves potential solvers through addressing extrinsic and intrinsic motivations for the solvers [Bullinger et al. 2009]. At the execution phase, the sponsor provides updated information to raise and maintain solvers' motivations. The sponsor also promptly responds to solvers' individual questions through emails [Bullinger et al. 2009].

We propose that sponsor-solver interaction can affect solution quality in two ways. First, such interaction will increase the number of solutions. The studies about the interactions between a company and consumers in the consumer virtual community highlighted the value of interactions with solvers to increase their community participation [Algesheimer et al. 2010; Jeppesen and Frederiksen 2006]. Feedback and simple invitation emails from the company can motivate consumers to join the community [Algesheimer et al. 2010; Jeppesen and Frederiksen 2006]. We expect a similar effect in crowdsourcing. Inviting solvers to join a crowdsourcing community will draw more solvers. Moreover, providing feedback for solutions can transfer the sponsor's ideas to solvers, who then can create more solutions based on the constructive feedback. The sponsors can come up with new creative ideas when communicating with other solvers. Hence, we propose

H4a: Sponsor-solver interaction is positively correlated with solution quantity.

Further, such interactions will increase solution diversity. Both solvers and the sponsor can develop new ideas through constant interactions. The sponsor can refine and develop ideas after reviewing the submitted solutions. These new ideas, or design elements, can be added to prior solutions, which will increase the overall solution diversity. This process functions like the "additive collaboration" programming crowdsourcing described in Howe [2008]. Gulley, a well-known software company, organizes a programed crowdsourcing to solve a common question called "traveling salesman problem." Gulley allows the participants to access each other's codes in order to create better solutions [Howe 2008]. By tweaking the participants' ideas, the overall solutions become more diverse.

The crowdsourcing contests we study in the current study are mainly ideation contests, such as graphic design, which need solvers' creative ideas, effort, and design skills. Compared with expertise-based contests in InnoCentive, which address how elaborative solutions should be [Bullinger and Moeslein 2010; Piller and Walcher 2006], the crowdsourcing contests studied in this paper are less complex. For creative design contests, the sponsor seeks creative ideas without rigorous verification. Therefore, we propose that for design contests, sponsor-solver interaction will lead to higher solution diversity, rather than a convergence of solutions.

The solvers can be motivated by nonfinancial reward [Leimeister et al. 2009; Zheng et al. 2011]. Feedback for solutions can be considered as a reorganization of the solver's talent, so that it can motivate solvers to exert more effort [Yang et al. 2009; Zheng et al. 2011]. This may generate more creative ideas for solving the crowdsourcing problem. Hence, we propose

H4b: Sponsor-solver interaction is positively correlated with solution diversity.

4. Research Method

4.1. Data Collection

We conducted our field study on www.680.com, a Chinese crowdsourcing platform. There were 2.7 million registered solvers and 98,000 crowdsourcing contests by the time the data were collected. In a sample of 7,178 new contests published in a period of nine months, we identified the top four categories of crowdsourcing contests, which were graphic design (4,383), website design (1,243), name and slogan design (1,086), and creative writing (356).

We surveyed crowdsourcing sponsors of graphic design and website design, which accounted for about 78.4% of the total contests. Graphic design and website design share some common features which require creative ideas from the solvers. Website design also requires solvers to master some programming skills. Both graphic design and website design are similar to beauty contests because the final outcome to these creative designs is subjective and does not have absolute performance evaluation benchmark for determining the winner [Terwiesch and Ulrich 2009; Morgan and Wang 2010].

Before data collection, we published a contest on www.680.com. We indicated that the nature of the contest was a research project, which aimed to understand how a sponsor obtained satisfactory solutions from the crowdsourcing platform. To motivate sponsors to participate in the survey, a lottery was set up with 1 first prize (300 RMB – Chinese currency Yuan Renminibi), 30 second prizes (100RMB), and 18 third prizes (50RMB). Within two months, we sent 1,186 invitations to sponsors (950 graphic design and 236 website design) after these sponsors closed their crowdsourcing contests. The invitation letter provided a link to an online survey about the latest crowdsourcing contest that the sponsor just conducted. The respondent was asked to provide the ID of the latest contest, in order for us to collect objective data, such as award, start times, end times, the number of solutions, and so on. We asked the respondent about his/her interactions with solvers, solution diversity, and solution quality in the online survey.

A total of 237 responses were received. After removing incomplete and duplicated responses, 157 responses were kept in the final sample, resulting in a response rate of 13.23%. While the rate seemed lower than conventional survey research, it was consistent with recent electronic commerce studies [Ke and Zhang 2009; Sen et al. 2008]. Sample statistics are shown in Table 1. We followed Armstrong and Overton [1977] to evaluate the issue of non-response and found that non-response bias was not present in the study.

Table 1: Description of Crowdsourcing Tasks

Characteristics	Mean	Std. Deviation
Amount of award (Chinese RMB)	490.24	638.31
Number of solutions submitted	39.85	38.23
Task duration (days)	20.52	25.28
	Frequency	Percentage
Task type		
Graph design	127	80.90
Web site design	30	19.10

4.2. Measures

Both objective and subjective measures were used in this study in order to reduce common method bias [Podsakoff et al. 2003]. Solution quantity, award, and control variables which included crowdsourcing type (1: graph design, and 0: web site design], crowdsourcing duration (days), and sponsor experience were measured using objective data from www.680.com. Others were measured using five-Likert scales in the online survey.

Based on Lam et al. [2004], we developed three items to measure solution quality, i.e., "I recognize that I received a satisfactory solution that has met the requirements," "I recognize that I am satisfied about the best solution I received from this crowdsourcing," and "I am satisfied about the solution quality in this crowdsourcing." To measure solution diversity, we referred to the study of solvers' expertise diversity [Howe, 2008] and the definition of solution variance [Terwiesch and Ulrich 2009]. We asked one item "The solutions I get from the crowdsourcing were diverse, i.e., each of the designs has its own unique characteristics." To measure sponsor-solver interaction, we reviewed the prior literature [Algesheimer et al. 2010; Howe 2008; Yang et al. 2009] and developed a three-item scale, i.e., "I answered every solver's queries in time," "I gave feedback and improvement suggestions to my preferred solutions in time" (e.g., as soon as I get the suggestions), and "I invited solvers to join my crowdsourcing contest actively after publishing it."

To improve content validity, we conducted open-ended discussions about the translated items with experts and professors who had both domain knowledge and methodology skills. A pretest was conducted with www.680.com sponsors, and a 500RMB reward was given. We made minor changes in the questionnaire according to 25 respondents' suggestions.

5. Data Analysis and Results

5.1. Scale Validation

We used PLS-Graph with bootstrapping to assess the significance of factor loadings and path coefficients. Reliability was assessed by means of composite reliability [Fornell and Larcker 1981]. As shown in Table 2 (single item variables were not included), all composite reliabilities were above 0.8, higher than the suggested cut-off value of 0.7 [Nunnally 1978]. Convergent validity was assessed by examining factor loadings and average variance extracted (AVE). Fornell and Larcker [1981] proposed factor loadings greater than 0.7 and AVE at least 0.5. Table 2 shows that the results met with these criteria, suggesting sufficient convergent validity. The cross-factor loadings in Table 3 also suggest satisfactory convergent validity. Discriminant validity was tested by comparing a construct's AVE to its variance shared with other variables. Fornell and Larcker [1981] proposed AVE of the construct higher than the variance shared with other variables. Table 4 indicates we had satisfactory discriminant validity.

Table 2: Measures

Construct	Item	Loading	Std. error	T-value	C.R.	AVE
Interaction					0.83	0.62
	Interaction-1	0.78	0.07	10.88		
	Interaction-2	0.82	0.06	14.76		
	Interaction-3	0.76	0.08	9.82		
Solution quality					0.95	0.87
	Quality-1	0.92	0.03	32.9		
	Quality-2	0.93	0.02	61.39		
	Quality-3	0.95	0.01	89.23		

Table 3: Factor Loadings and Cross-Loadings

Item	Interaction	Solution quality
Interaction-1	**0.81**	0.22
Interaction-2	**0.79**	0.21
Interaction-3	**0.76**	0.24
Quality-1	0.24	**0.83**
Quality-2	0.23	**0.83**
Quality-3	0.24	**0.84**

Table 4: Inter-construct Correlations

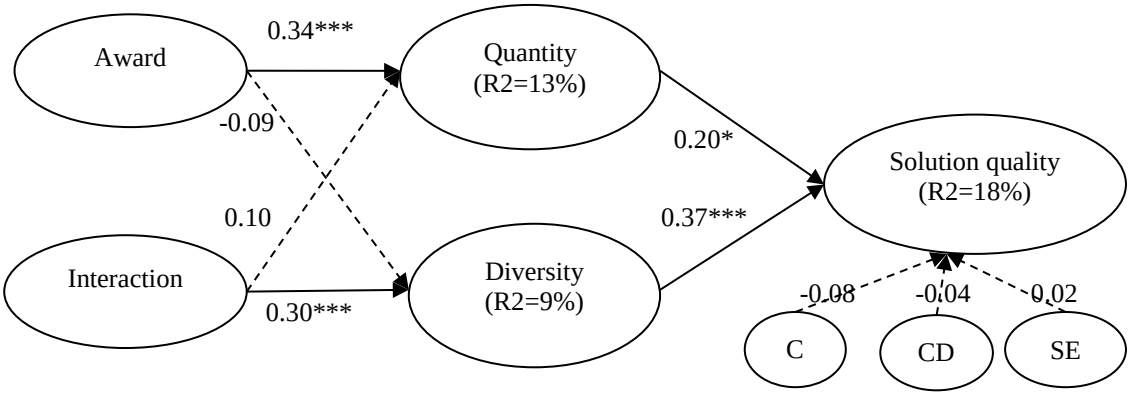
	1	2	3	4	5	6	7	8
Solution quality (1)	0.93							
Solution quantity (2)	0.19	n.a.						
Solution diversity (3)	0.39	0.10	n.a.					
Award (4)	-0.03	0.35	-0.07	n.a.				
Interaction (5)	0.24	0.12	0.29	0.07	0.79			
Crowdsourcing type (6)	0.07	0.50	0.13	0.01	-0.07	n.a.		
Crowdsourcing duration (7)	-0.01	0.30	-0.08	0.46	-0.03	0.01	n.a.	
Sponsor experience (8)	0.03	-0.14	0.08	0.07	0.13	0.01	-0.10	n.a.

Note: square root of AVE shown on the diagonal. n.a.: single-item scale.

5.2. Hypothesis Testing

The results are shown in Figure 2 and Table 5. The model explained 18% of the variance in solution quality, 13% of the variance in solution quantity, and 9% of the variance in solution diversity. In terms of individual path, solution quantity had a significant effect on solution quality ($p<0.05$), supporting H1. Solution diversity had a

significant impact on solution quality ($p<0.001$). Therefore, H2 was supported. Award was significantly correlated with solution quantity ($p<0.001$), indicating that H3a was supported. However, award was not a significant antecedent of solution diversity, not supporting H3b. The effect of sponsor-solver interaction on solution quantity was not significant, suggesting that H4a was not supported. However, interaction was significant for solution diversity ($p<0.001$). Therefore, H4b was supported. All the control variables had no significant effects.



CT: contest type; CD: contest duration; SE: sponsor experience
Note: * $p<0.05$, *** $p<0.001$

Figure 2: Hypotheses Testing

Table 5: Hypotheses Testing

Hypotheses	Coefficient
H1: solution quantity -> solution quality	0.20*
H2: solution diversity -> solution quality	0.37***
H3a: award -> solution quantity	0.34***
H3b: award -> solution diversity	-0.09ns
H4a: interaction -> solution quantity	0.10ns
H4b: interaction -> solution diversity	0.30***

Note: * $p<0.05$, ***$p<0.001$, ns: non-significant

6. Discussion

The support for H1 verified the importance of solution quantity in crowdsourcing. Yang et al. [2009] proposed solution number as a proxy for crowdsourcing performance. Hautz et al. [2010] suggested that more solutions could increase the probability of getting an ideal solution. However, both studies did not test the relationship between solution quantity and solution quality. This finding was not consistent to Lakhani et al. [2007], which did not find a significant effect of solution number on crowdsourcing problem's solvability. The research context may help explain the inconsistency. Lakhani et al. [2007] examined InnoCentive, which is an expertise-based crowdsourcing platform. For expertise-based crowdsourcing, solution quantity did not affect the sponsor's payoff [Terwiesch and Xu 2008]. In the current study, as well as Yang et al. [2009] and Hautz et al. [2010], the crowdsourcing contests were mostly ideation challenges.

Consistent with Howe [2008], Page [2007], and Terwiesch and Ulrich [2009], this study found support for H2. In addition, we found support for Lakhani et al. [2007], which proposed that diversity might prevail over the number of solutions in crowdsourcing. Compared with solution quantity, the effect of solution diversity almost doubled that of solution quantity (0.37 vs. 0.20). This suggested that solution diversity was the more important antecedent. Though the research context was design contest, diversity power also worked for other types of crowdsourcing tasks, such as research and development as well as problem solving in Innocentive [Jeppesen and Lakhani 2010]. Drawing the knowledge from diverse external sources is an effective mechanism to solve internal problems [Jeppesen and Lakhani 2010].

Award was found to be an effective predictor of solution quantity (H3a), consistent with previous research [Archak 2010; Terwiesch and Xu 2008; Yang et al. 2009]. However, award did not affect solution diversity (H3b). The possible reason for this insignificant effect was the empirical setting. Design contest was one type of ideation contests which needed more creative thinking than the solver's effort and skills. In design contests, solvers' creativity, innovative capabilities, and intrinsic motivation may be more salient than extrinsic motivation, such as award in the current study.

Further, sponsor-solver interaction did not have a significant effect on solution quantity (H4a), but on solution diversity (H4b). The reason may be that after interacting with the sponsor, solvers may revise their existing solutions rather than submitting new solutions if they get new creative ideas. Therefore, interaction did not increase solution quantity, but helped solvers to refine their submissions.

The supports for H3a and H4b imply that crowdsourcing award had an indirect effect on solution quality through solution quantity, and that interaction had an indirect effect through solution diversity. By calculating the total effects of award (0.34*0.20=0.07) and interaction (0.30*0.37=0.11) on solution quality, interaction seems to be more important than award.

7. Conclusion

7.1. Limitations

First, the findings may not be applied to other types of crowdsourcing contests, such as expertise-based crowdsourcing [Terwiesch and Xu 2008]. Future studies may investigate other types of crowdsourcing contests to examine the generalizability of the research model. Second, the empirical study was conducted in China. While the research findings may complement the prior literature that was focused on the western countries, the findings may not be applicable in the West. Third, a single-item scale was used to measure solution diversity; and therefore, we were not able to examine the reliability and validity of the scale. However, we tried to assure its content validity based on prior literature [Howe 2008; Terwiesch and Ulrich 2009; Page 2007]. Future studies may develop a multi-item scale. Using an objective measure of solution diversity, such as content analysis of solutions, may be an alternative approach. Fourth, we only studied the interaction between sponsor and solvers from the sponsor's perspective. Future studies may collect dyadic data from both sides to measure the construct.

7.2. Implications for research

This study makes several contributions to crowdsourcing research. First, we identify solution quantity and solution diversity as two wheels of the wagon driving optimal solution quality. This study is one of the first crowdsourcing studies to examine these two competing and complementing factors in the same research model. Such an approach allows us to simultaneously investigate the two factors and evaluate their tradeoffs. Unlike prior work [e.g., Yang et al. 2009] which considers the number of solutions as a proxy of contest performance, we found that solution quantity does not play the same significant role as solution diversity does in determining the quality of solution. Instead, solution diversity is more important than solution quantity. Because of the limit of the study, we do not reveal the relationship between solution quantity and solution diversity, although the common knowledge suggests that solution quantity is a precursor of solution diversity. Future studies can investigate such relationship.

We find that contest award and sponsor-solver interaction influence optimal solution quality, by two complementary routes via solution quantity and solution diversity respectively. While award is more important in reaching a higher solution number, interaction makes a significant contribution to solution diversity. Interaction is found to be more useful than award in improving solution quality. Future studies can investigate whether these two paths hold in other contexts, such as expertise-based contests in InnoCentive.

Second, we have attempted to solve the puzzle of whether the sponsor should interact directly with solvers. Previous research is largely focused on the mechanism of InnoCentive, which does not support open communications between the sponsor and solvers [Chesbrough 2006].The major benefit of this indirect communication is that the sponsor can conduct crowdsourcing contests anonymously and keep business secrets [Chesbrough 2006]. We feel that this approach may not be the universal strategy for crowdsourcing in other contexts and countries.

It is known that people in the East emphasize the culture of collectivism, rather than engaging in independent tasks. In addition, communication in the East is highly context-based, which means that latent and indirect information is implied between the lines of messages. Therefore, people require more explicit and face-to-face communications beyond written communications. The solvers in the crowdsourcing practice may feel written contest descriptions insufficient for them to pursue solutions. They may regard it a norm for the sponsor to work closely with them. The sponsors may also consider it their responsibility to address the solver's questions and concerns directly.

Third, we have applied a rigorous research method to test the research model. In terms of data collection, previous studies have relied on either objective data collected from the crowdsourcing platform or subjective data collected from sponsors and solvers. This study is one of the first to use both objective data and subjective data in the empirical investigation. In terms of measures, we adopted a different perspective by examining the issue of solution diversity from the sponsor's subjective view [Lakhani et al. 2007; Terwiesch and Ulrich 2009]. While most of the extant research evaluates diversity in terms of the range of solvers' expertise [Howe 2008; Page 2007; Jeppesen and Lakhani 2010], we posit that such expertise is a necessary, but not sufficient, determinant of solution diversity. We believe that the evaluation of diversity should be up to the stakeholder of the crowdsourcing, which is the sponsor.

Last, the research findings based on a crowdsourcing platform in China are able to complement the majority of literature focused in Europe and America. In addition to the several differences we have identified between China and the West, future studies can further investigate other differences. Advancing the knowledge about different crowdsourcing practices among different countries may provide the opportunity to develop middle-range theories relevant to the unique economic and cultural environments where the crowdsourcing practices are conducted.

7.3. Implications for practice

This research provides some practical implications for crowdsourcing sponsors and platform providers. First, sponsors, especially ideation crowdsourcing sponsors, should make every effort to achieve solution diversity, as well as solution quantity—both of which are significant determinants of solution quality. More importantly, sponsors should pay attention to solution diversity, which seems to be more important than solution quantity. It is necessary for sponsors to develop various strategies to motivate people from a diverse range of backgrounds and experiences that are the sources of solution diversity. The current study proposes that one such strategy is the interaction with solvers. Sponsors should be proactive and responsive in their interactions with solvers. After posting a crowdsourcing contest, inviting specific solvers is necessary. It is also critical for sponsors to give solvers feedback and suggestions when sponsors come across preferred solutions. Also, sponsors should answer solvers' queries as soon as possible.

Second, the providers of crowdsourcing platforms should develop and improve communication tools to facilitate interactions between sponsors and solvers. These operators should encourage sponsors to disclose different types of contact information, such as email addresses, phone numbers, and instant messaging. Through these private interaction methods, solvers can communicate directly with sponsors. Finally, although crowdsourcing award did not have a significant effect on solution diversity, they are a significant precursor of solution quantity. Therefore, sponsors should carefully determine the strategy of award.

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