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Experimental Investigation of the Impact of Risk Preference on Construction Bid Mark-Ups

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Abstract

Risk preference plays an important role in decision-making. The objective of this paper is to show how much risk preferences influence bid price decision-making in bidding for construction contracts. Based on the literature review and interviews, we designed a bidding situation and conducted an experiment to test decision maker responses. 172 participants with lengthy experience in bidding for construction work took part in the experiment. Both descriptive statistics and regression analysis are used for deep information mining of the data. We find that risk preference has a significantly positive effect on bid mark-ups. Based on a comparison of the influences of risk preferences on the bid price in different competitive bidding situations, we find that the bid price decreases with the number of bidders and it is even lower when the number of bidders is unknown. Therefore, considering both risk preference and the number of bidder is

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important to make a reasonable bid decision making. Finally, advice is also provided to construction companies for evaluating the leader's decisions and decision-making team.

Keywords: bidding, mark-ups, risk preference, experiment

Introduction

For building contractors, the bidding process occurs at the start of a project, and whether the bid decision is reasonable or not has a direct impact on the success of the project (Liu and Josephson 2013). The bid price plays an important role in determining whether contractors can win the construction contract and whether they can make a satisfactory profit when the work is completed (Ishii et al. 2011). It is clear that bidding decisions involve a typical kind of risky decision-making, but the relationship between the risk preference and bid price of contractors has yet to be clearly articulated in the literature (Laryea and Hughes 2008). In response, this paper focuses on the influence of risk preference on the bid prices of contractor in different bidding scenarios.

The bid price can be divided into two main parts: the construction cost and a mark-up (Lan et al. 2007). The construction cost is usually estimated based on expected resource consumption, which is derived from the tender documents, and the unit price of each work activity. Hence, the construction cost component for each bidder should be quite similar. That is to say, the major difference in bid prices for a contract could be due to the differences between mark-ups which at least partially depend on the bidders' risk preference. The purpose of this study, therefore, is to explore how bidders' risk preferences affect a contract's mark-ups.

Neither the construction cost nor the mark-up is known by the owner and each bidder only knows its own. One way a bidder can estimate the mark-up of its competitors is to deduct its own construction cost from its competitors' bid prices. However, this is unlikely to be sufficiently accurate in practice, as there is always a substantial difference in the expected construction cost of each bidder because of information asymmetry. In addition, there is no standard for calculating the mark-up, no detailed account of how contractors actually take account of risks when arriving at their bid price, and even no evidence that the pricing process is systematic at all in nature (Laryea and Hughes 2008). Therefore, how to obtain data of the mark-up based on the bidders' real intentions is the key point of our study.

It is noteworthy that bidding strategies can have a large influence on bid prices (Conejo et al. 2002). Sometimes bidders may give up their profit or even accept a loss to win the contract based on a new market-entry strategy. However, such a strategy is uncommon and irregular. This study is therefore based on the most common strategy of attempting to maximize profit. In this research, we conducted an experiment with contractors' middle-senior managers or experienced staff as our participants. The experiment contains two major test items. In the first test, the participants' bid price was obtained by the designed bidding scenarios while, in the second test, the participants' risk preference was elicited by a classical lottery choice task that is widely adopted in other studies (Brick et al. 2012; Bruhin et al. 2010; Qiu et al. 2014). In total, 172 participants took part in the study. We employ a linear regression model to analyze the relationship between the mark-up and

risk preference. The estimated results support the significant role of risk preference in the formation of bid prices.

Related Work and Research Motivation

Bidding for contracts involves a crucial strategic decision for contractors' contribution to sustainability in the construction industry (Jarkas 2013). To decide an optimum bidding price can not only maximize the probability of winning a construction project, but realize proper profit (Abotaleb and El-adaway 2016). For a specific bidding situation, there are two crucial decisions to make: to bid or not to bid and, if to bid, the mark-up in the bid price (Shafahi and Haghani 2014). Wallwork (1999) argued that the contractors' ability to determine the 'right' price level and win the 'right' contract is of equal importance for survival and making a profit. Studies of bidding decisions have focused on the following aspects. Firstly, studies investigate the factors influencing bidders' decisions on whether to bid or not to bid under different conditions. For instance, Han et al. (2005) found a prevailing risk aversion between bidders for a complex international construction project when they made a to bid or not to bid decision. El-Mashaleh (2012) proposed an empirical framework for making the bid/no-bid decision by deciding on the key bidding factors involved and utilizing data envelopment analysis to make decisions. Jarkas et al. (2013) identified, explored, and ranked the relative importance of the critical factors determining contractors' decisions to bid or not to bid for local construction projects. Chen et al. (2015) studied the relationship between a decision maker's risk perception, risk propensity and the 'to bid' or 'not to bid' decisions for construction projects. Shokri-Ghasabeh et al. (2016) ranked the critical factors

affecting ‘to bid’ or ‘not to bid’ decision-making, dividing 26 factors into 4 categories (market, contractor, client and contract). They found the most significant factors were client financial capability, project risk, project future benefits and profitability, and number of competitors/bidders. Secondly, several studies have been devoted to understanding the factors affecting the mark-up decision in the bidding phase. For instance, Shafahi and Haghani (2014) revealed the importance of eminence and previous work for the mark-up decision in project selection. Jarkas (2013) identified 10 primary factors that affect the mark-up decision of contractors in the construction industry. Lan et al. (2007; 2010) modeled the mark-up behavior and heterogeneity of contractors, identifying the prominent factors influencing mark-up behavior as market conditions, number of bidders, project type and project size. For the ‘to bid’ or ‘not to bid’ decision, most studies have focused on the effect of risk factors on the contractors’ decisions. In considering the factors affecting the mark-up decision, on the other hand, studies have focused more on factors relating to project characteristics and market competition conditions rather than contractor-related factors. Nevertheless, the bidding process mainly depends on contractors’ emotional responses, intuition and previous experience (Fayek 1998; Mochtar and Arditi 2001). For mark-up decisions, therefore, factors originating from the bidders themselves should not be ignored. Moreover, bidding decision-making is a typical kind of risky decision-making (Lin and Chen 2004), including how to make appropriate risk sharing between the contracting parities (Hyari 2016). Thus, the aim of this paper is to investigate the influence of bidder-related factors, especially risk preference, on mark-up decisions.

As the bidding decision is essentially a kind of risk decision (Lin and Chen 2004), the decision-maker's risk preference related factors will have an influence on the bidding decisions (McDougalt 1995). For this study area, there are two common conditions - known probability and unknown probability.

Known Probability

Risk preference describes what one does when faced with a risky option and a safer alternative, and is an important predictor of behavior under risk (Hsee and Weber 1997). As Mellers and Cooke (1994) point out, no decision model can describe all risk decision behaviors. The behaviors may not only be influenced by factors regarding circumstances, but also risk preference. Of all of these risk decision behaviors, most people are risk averse and few are risk loving (Holt and Laury 2002), which is an universal phenomenon in both theory and practice. Risk aversion is a fundamental element in standard theories of lottery choice, asset valuation, contracts and insurance (Arrow 1965; Pratt 1964). There are also studies focusing on risk preference in bid decision making. Li et al. (2003), for example, presented a methodological framework of optimal bidding strategies in a risk-constrained environment. Similar to this study, a FTR (point-to-point right, a type of financial transmission right) bidding strategy in electricity markets was proposed based on the bidder's expected utility (Li and Shahidehpour 2005), while Zare et al. (2010) provided a technique based on information gap decision theory to derive a bidding strategy in the day-ahead market of a large consumer. All these studies have already shown that risk preference is an important issue in bidding, but few focus on the extent to which the influence is. This study is therefore cognizant of this point.

Unknown Probability

In decision theory, there is a distinction between risky prospects, where the probabilities of outcomes are objectively known, and uncertain prospects where these probabilities are unknown or vague. According to Knight's (1921) point of view, risk can be appraised with some probability while uncertainty is not measurable, while Ellsberg (1961) found that people place a higher value on bets with known probabilities of success (risks) than bets with unknown probabilities (uncertainties), naming this preference as "ambiguity aversion". Barham et al. (2014) define uncertainty to comprise two components, risk and ambiguity. Risk preference is the preference to accept of outcomes with a known probability, and ambiguity preference is the additional preference to being unsure about the probabilities of outcomes (Barham et al. 2014). Therefore, attitudes to risk (known probabilities) and attitudes to ambiguity (unknown probabilities) are two separate constructs, both of which influence decision making (Blankenstein et al. 2016). However, it does not mean that risk preference does not exist in the context of unknown probability. Most studies have worked on the model of ambiguity preference. The seminal works of Schmeidler (1989) and Gilboa and Schmeidler (1989) laid a formal foundation for this theory by modifying Savage's (1954) subjective expected utility model. Ambiguity preference has also been successfully combined with other study topics, such as comparative ignorance (Fox and Weber 2002; Rubaltelli et al. 2010) and market incompleteness (Mukerji 1998; Mukerji and Tallon 2001). From all these potential topics, risk preference is the most complementary with ambiguity preference, which measures preferences in uncertain circumstances in different degrees. For this reason, many studies

combine these two kinds of preferences into one (Barham et al. 2014; Hayashi 2005; Machina 2009). In our study, we particularly focus on how much influence risk preferences have on contractors' bid prices. Therefore, the probability of outcomes is known in our research design.

Based on the above review of previous studies, we find that most studies focus on bidding decision-making including the 'to bid' or 'not to bid' and mark-up decisions. Previous research has studied the impact of different project characteristics and risk factors on the to bid or not to bid decisions in detail, with some exploiting the effect of objective factors, such as project characteristics, on the mark-up decision. However, the bidding process mainly depends on the contractors' emotional responses, intuition and previous experience (Fayek 1998; Mochtar and Arditi 2001) and bidding decisions involve a typical kind of risk decision-making (Lin and Chen 2004). Consequently, it is of significance to probe into the little understanding on relationship between risk factors such as risk preference and mark-up decision-making. To fill this gap, this paper adopts an experimental investigation to explore the impact of risk preference on the mark-up component of bids. To collect real bid data of this kind for past projects is impossible because of the commercial confidence and the number of bidders involved (Lan et al. 2007). Consequently, a bidding experiment is used to test the relationship between risk preference and mark-up in bid pricing.

Experiment

The participants

The participants were recruited from two top Chinese contractors and their subcontractors

and suppliers. To protect their privacy, we denote them company A and B. As of 2015, company A has 136,655 employees and the company B has 196,368 employees. The basic rule in selecting participants is they should have adequate working experience (over 10 years) in the construction or related industry. In total, 172 participants were recruited. The sample description shows that the average age of participants is 31 years old, and male and female participants account for 66% and 34% respectively. 52% of participants have been married. In addition, 95% of participants have received a college education, 14% of participants are senior managers, 43% are middle project managers and 43% are technical staff. Moreover, of the 172 participants, 49% have 10-15 years' work experience, 33% have 15-20 years' work experience, 13% have 20-25 years' work experience and 5% have over 25 years work experience. The average work experience of the participants is 17.8 years and of 50% of the participants have bid experience. The income level of participants is divided into five categories (based on the pilot survey). Of the 172 participants, 37% have an annual income between CNY 30,000 and 80,000, 34% between CNY 80,000 and 130,000, and only 6% higher than CNY 230,000 (CNY 1 = USD 0.15 at the survey date). More detailed information concerning the participants is provided in Table 1.

The process of experiment

A pilot study was conducted before carrying out the formal experiment and survey to ensure the validity of the experimental design and appropriate measurement of the variables of interest. The experiment involves four steps as follows:

Step 1: After the participants entered the laboratory, the researchers distributed experiment

introduction and number cards, which were used to decide each participant's seat and replace the participant's name. The researchers then introduced the experiment to the participants and informed them that the experiment was anonymous and they were not allowed to communicate in any form. Each participant was paid CNY 50 upon completing the experiment.

Step 2: The researchers conducted a lottery choice task developed by Harrison et al. (2005), to elicit the participants' risk preference. The choice sets are shown in Table 2. The bidders had to decide from which point they started to shift their choice from the risky option to the safe option. We thus use the shifting point to measure the extent of the participants' risk preference. The risk preference of participants in our research can be categorized as risk averse, risk neutral and risk loving, based on the ratio between the certainty equivalent at the switching point and the expected value for each lottery. The participant is risk loving if the ratio is greater than one, is risk neutral if the ratio is equal to one, and is risk averse if the ratio is smaller than one. However, this does not mean risk averse and risk loving are bipolar risk preferences. Risk averse and risk loving are relative concepts and depend on the comparison with other subjects. The lottery choice task can be regarded as the "gold standard" of risk-related preference in the experimental literature (Anderson and Mellor 2009) and is also well-known as the "multiple price list" method (Coller and Williams 1999; Harrison et al. 2002). Many previous studies have used this method to measure risk preference (Baker et al. 2008; Barreda-Tarrazona et al. 2011; Filippin and Crosetto 2016; Holt and Laury 2002; Levy et al. 2011; Mckenna et al. 2007). Moreover, in this study, we consider risk preference as an intrinsic attribute of an individual and thus not contextually dependent. Therefore,

it is reasonable to use lottery choice to measure individual risk preference in the bidding scenario we designed. In addition, to account for the external validity of elicited preferences in the laboratory, recent experimental studies have investigated the relationship between elicited preferences and actual behaviors in reality, and find that the elicited preferences largely explain the real-word behaviors (see Liu, 2012; Meier and Sprenger, 2010; Nielsen, 2001). Hence, we argue that the game-like 'experiment' can be translated into real-world behavior.

Step 3: The aim of this step is to obtain each participant's bidding price. The researchers introduced the bidding scenario to the participants, and then the participants made a bid for the project based on the cost of project stated on the cost card that was placed on the seat in advance. More detailed information about the bidding scenario is demonstrated in the bidding scenario and decisions needed section following.

Step 4: In this step, the participants completed a questionnaire concerning basic individual information such as gender, age, education background, marital status, income level, work experience and bid experience.

The bidding scenario and decisions needed

The participants were placed in the position of a general manager of a construction company, with the following bidding scenario:

> The company's leaders reach a consensus that your company is going to take part in bidding for a 30,000 m^2 department store project located in the southeast of the Third-Ring Road in Beijing. It has a framed structure, with one underground and eight aboveground floors.

The scope of work contains the main structure of the building and installation of all equipment. Decorations and air-raid shelters are not included in the scope of work and all materials are supplied by the employer. There is a relatively flexible timetable for construction and the cash deposit is reasonable. The employer will make prepayments and progress payments in good time.

All the work will be completed by your company with no subcontracting. Now, as a member of the company's leadership, you and your team have to decide the bid price (calculated per square meter floor area). We also make the hypothesis that all the bidding companies have nearly the same bidding situation. They satisfy all the requirements of the employer and they have enough workforce for the project. This kind of department store is used as the experimental project because this form of building is widely constructed. The technical difficulties are also lower than other kinds of project. Therefore, more participants will have a good understanding of the project even they do not work on this kind of project as most construction industry employee have a basic understanding of this kind of project even their company does not undertake them.

All participants have over 10 years working experience of building construction, but have no construction experience in Beijing. They are also experienced construction industry practitioners and make their own judgments. Therefore, their evaluation of construction cost may be different, which will have a direct effect on their bid price. To eliminate this effect, we set 10 cost values of CNY 2000, 2500, 3000, 3500, 4000, 4500, 5000, 5500, 6000 and 6500. We then wrote these 10

values on cost cards and randomly placed a card on each seat. No matter how much the participants considered the costs would be based on their experience, they had to use the specific cost value on the card, which we prepared on each seat in advance, as their estimated cost. These values were set with an average dispersion of the possible cost range and were confirmed in consultation with six construction company managers. We employed a first price auction mechanism to elicit bid prices. After the bidders drawn their cost values, they were presented with three different competitive market environments in turn, comprising 4 potential bidders (including the participant), 8 potential bidders (including the participant) and the number of bidders was unknown. The bidders needed to decide their bid price in each competitive environment based on their costs and the competitive environment (number of bidders).

Results

Before carrying out the regression to investigate how risk preferences influence bid prices, the descriptive results for the risk preference and bidding outcomes are presented in Table 3.

As shown in Table 3, the average shifting point is at 43.99, and the corresponding ratio between the certainty equivalent at the switching point and the expected value is 0.88 It indicates that participants are on average risk averse. For the assumed project, the average construction cost is CNY 4225, with an average bid price of CNY 5246.6, 5000.8 and 5099.9 when there are 4 bidders, 8 bidders and the number of bidders is unknown respectively. The average mark-ups are CNY 1021.60, 775.80 and 874.90 when there are 4 bidders, 8 bidders and the number of bidder is unknown respectively. Consistent with expectations, therefore, the bid price decreases with the

increase in bidders (average bid price of 4 bidders is 5246.6 and average bid price of 8 bidders is 5000.8). Nevertheless, the bidders tend to bid less when the probability is unknown than when it is known (average bid price with known probability is 5123.7 and average bid price with unknown probability is 5099.9).

Risk preference and mark-ups

In this paper, we use the linear regression model to test the effect of risk preference on bidding behavior. The dependent variable is the mark-up and the control variables are age, gender, education, marital status, income level, cost, work experience and bid experience. The factors found to influence bid mark-ups decision in previous studies mainly include project characteristics, company characteristics, the bidding situation and economic environment (Dulaimi and Shan 2002; Lan et al. 2010). However, these studies ignore the individual characteristics of bid mark-up decision makers. In contrast, our research focuses on risk preference, which is one of the individual characteristics affecting mark-up decisions. In addition, the previous experience of employers and previous experience with similar projects are also critical factors that may have an influence on bid mark-up decisions (Jarkas et al. 2013), so we also chose work experience and bid experience as our control variables. Moreover, through interviews with practitioners, we found that cost is another critical factor that has an influence on bid mark-up decisions, so cost is also chosen as a control variable in our research. Therefore, in addition to the basic individual characteristics we need to control for, we finally use eight variables (age, gender, educational background, marital status, income, work experience, bid experience and cost) as our control variables in the model.

For the main variable of interest for our study, we use the value of shifting point to measure the extent of the participants' risk preference. The estimated results are quite close if we instead use the ratio between the certainty equivalent at the switching point and the expected value to measure risk preferences (See Table 6 in Appendix I).

Mark-up is the dependent variable in all models in Table 4. We report the estimated results under the three bidding environment (4 bidders, 8 bidders and unknown number of bidders). Model 1 in Table 4 tests the effect of risk preference on mark-ups without any control variables in the context of 4 bidders, and Model 2 in Table 4 includes the above stated control variables plus the risk preferences in the context of 4 bidders. As expected, the bid price significantly increases with cost, and risk preference has a positive effect on mark-ups at the 1% significance level. Model 3 in Table 4 tests the effect of risk preference on mark-ups without any control variables in the context of 8 bidders, and Model 4 in Table 4 includes the control variables plus the risk preferences in the context of 8 bidders. Again, risk preference has a significantly positive effect on mark-ups. Model 5 in Table 4 tests the effect of risk preference on mark-ups without any control variables in the context of unknown number of bidders, and Model 6 in Table 4 includes the control variables plus the risk preferences in the context of unknown number of bidders. Again, risk preference has played a significant role in determining the mark-ups no matter whether we include or do not include the control variables. Except the cost variable, no other individual characteristics have produced statistically effects on the mark-ups. The results indicate that the significant effect of risk preference on mark-ups is dominating regardless of the market environment (4 bidders, 8 bidders

and unknown number of bidders). Therefore, the significant influence of risk preference on bid price is further verified. Our findings support Cox et al. (1982) theoretical prediction of the important role of risk aversion in bidding behavior and accord with the early experimental findings of Cox et al. (1988). It is should be noted that we also test the effect of ambiguity preference (risk preference under unknown probability) on mark-ups, but the main purpose of our research is to test the relationship between risk preference and mark-ups. The results of testing both risk preference and ambiguity preference are not reported here to avoid possible confusion, and are left for future reporting. However, the results are available upon request

Mark-ups and the number of bidders

In this section, we compare the difference in mark-ups between the scenarios with different numbers of bidders. Figure 1 shows the median value of mark-ups under 4 bidders is the highest and the median value of mark-ups under the unknown number of bidders is higher than 8 bidders. The same results apply for the mean value. When the number of bidders is known (4 bidders and 8 bidders), the bid price decreases with the number of bidders. Moreover, we can conclude from Table 3 that bidders prefer to have higher mark-ups when the number of bidders is known (the mean value of mark-ups when the number of bidders is known is 898.7, and the mean value when the number of bidder is unknown is 874.90). In principle, therefore, our findings demonstrate that bid price decreases with the number of bidders, and even further when the number of bidders is unknown.

Mark-ups and different costs

In this section, we compare the differences of mark-ups at different cost levels. As Table 5 demonstrates, when the cost is equal to 2000, the ratio of the average mark-up to cost is the highest no matter in which scenario, and when the cost is equal to 6500, the ratio of the average mark-up to cost is the lowest no matter in which scenario. We also test the relationship between risk preference and mark-up at different cost levels (see the Figure 2 in Appendix II). Except in two cases where cost is the highest and the lowest, the relationship between risk preference and mark-ups is positive.

Discussion

To sum up results several main conclusions may have an underlying cause attributable to the special nature of the construction industry. These are analyzed and demonstrated further in this section in terms of the relationship among mark-ups, risk preference and the number of bidders.

The relationship between mark-ups and risk preference

Bidders who offer higher mark-ups are likely to obtain more profit once they win the contract, but they also face a higher risk of losing the contract. However, in today's international construction market, the construction capacity of contractors is far larger than the amount of work they can obtain – the contractors' demand for construction work exceeds the supply of contracts available. Therefore, there is unavoidable price competition all around the world in this industry. Moreover, the lowest bidder is most often awarded the contract. Although this method is not used in every auction, it is the case that all the bid prices are reasonably close to each other as they are

based on similar construction costs, even for bidders with very high-risk preferences, and our regression results also show there is a significant and positive effect of risk preference on the mark-ups. This is consistent with the findings of other studies, such as Kim and Reinschmidt (2010) concluded that high risk seeking companies tended to have a high mark-up. Awwad et al. (2015) also confirmed this result by using agent-based model to develop a virtual laboratory for construction bidding. This result shows that contractors incline to take the risk of biding to high and not winning contracts, rather than take the risk of bidding to low and making a loss of profit. Therefore, the mark-up decision is a trade-off between the two risks. However, with our data from experienced construction industry practitioners, we also know that the bid price is controlled to be within a competitive range even when taking a greater risk. In addition, the risk preference of the company leaders has far more influence on the bid price than those responsible for simply calculating the cost value. Therefore, when a company has a special bidding strategy, the leader needs to deliberate whether the decision reflects this strategy or it is affected by the leader's own risk preference. If the decision is made by a team, the staffing of the team is also an important issue. Members with a similar risk preference will come to an agreement relatively easily in the bid price discussion, but may lead to an extreme result. On the other hand, the decision-making team may want to be inclusive when members have different risk preferences, which can make progress quite difficult. Hence, the selection of the team members needs to involve the overall consideration of the company's organizational culture, strategy and risk preference.

The relationship between mark-ups and the number of bidders

The overall conclusion of this study is that mark-ups decreases with the number of bidders, which is consistent with the Lan et al. (2007) and bidders generally bid price even lower in our scenarios when the number of bidders is unknown. However, around a quarter of the bidders raised their prices or kept them unchanged when the number of bidders increases. Short interviews with the participants revealed two main reasons for this. Firstly, their bidding experiences have a direct effect. Some come from influential enterprises or family-owned construction companies that have trustworthy products and a good reputation, which makes them confident in the bidding process. Therefore, their bid price is relatively stable irrespective of the competitive situation, with the cost and mark-ups being generally unchanged. Secondly, some participants believe the probability of winning the contract is 1/8 or less and small changes in bid price make little difference to this. So they treat the situation as a lottery and raise their prices as a kind of bet that there is no need to regret even they lose the contract. Therefore, different bidding experiences and assessment of the competition status has a significant influence on bidding strategy as reflected by the bid price.

Conclusion

Bid price decision making is of particular significance in the construction industry. However, previous studies have yet to explain the precise relationship between the bid price and risk preference of contractors. To fill this gap, this study adopts an experimental method and survey to explore the relationship between risk preference and bid price. The findings show that risk preference has a significant and positive effect on bid price no matter whether the number of bidder

is known or unknown. In addition, the bid price decreases with the number of bidders, and is even lower when the number of bidders is unknown. We explain these results by comparisons with the literature and practitioner interviews. Our explanation of these results may offer practitioners a new perspective to consider when making mark-up decision in bidding. Also, this study contributes to the bid decision-making body of knowledge in uncovering the influence of risk preference on bid pricing.

Whereas the study provides noteworthy research results about the relationship between risk preference and mark-ups in construction industry, it also has some limitations. First, the participants in the research were recruited from two top Chinese contractors and their subcontractors and suppliers (these two top Chinese contractors account for a large share of construction work in China and both are in the Engineering News-Record Top 250 list). Although the results may provide a good explanation for large companies, their properties still cannot be generalized to other companies/regions/counties without further investigation. To further improve generalizability and external validity of the research results, it is suggested increasing diversity of samples in future research. Second, risk preference and ambiguity preference are two different constructs in decision theory. To test their different effects on mark-up in the unknown probability context is the next step for future research. Third, based on our interviews with a few practitioners, there are numerous other potential factors may also have an influence on the bid price. Future research needs to explore the relationship between other factors, such as organizational (trust and

empowerment) and cultural differences and bidding behavior, especially in terms of mark-up decision-making.

Appendix I:

Table 6 provides the regression results of risk preference with mark-ups. In all 6 models, we measure risk preference based on the ratio between the certainty equivalent at the switching point and the expected value of each lottery.

Appendix II:

Figure 2 shows the relationship between risk preference and mark-ups after controlling cost.

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Figures

Fig. 1. Different mark-ups in different bid scenarios

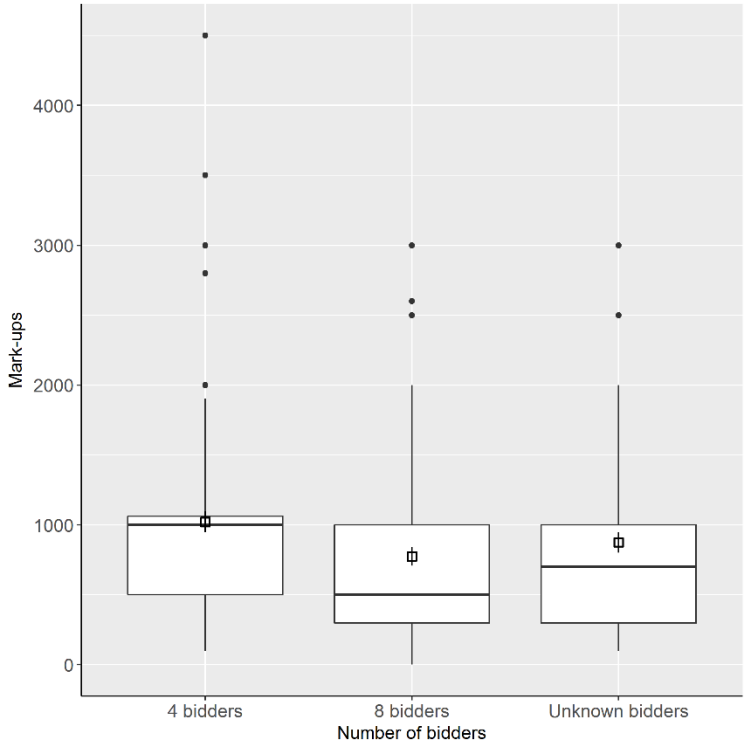

Fig. 2. Relationship between risk preference and mark-ups after controlling cost

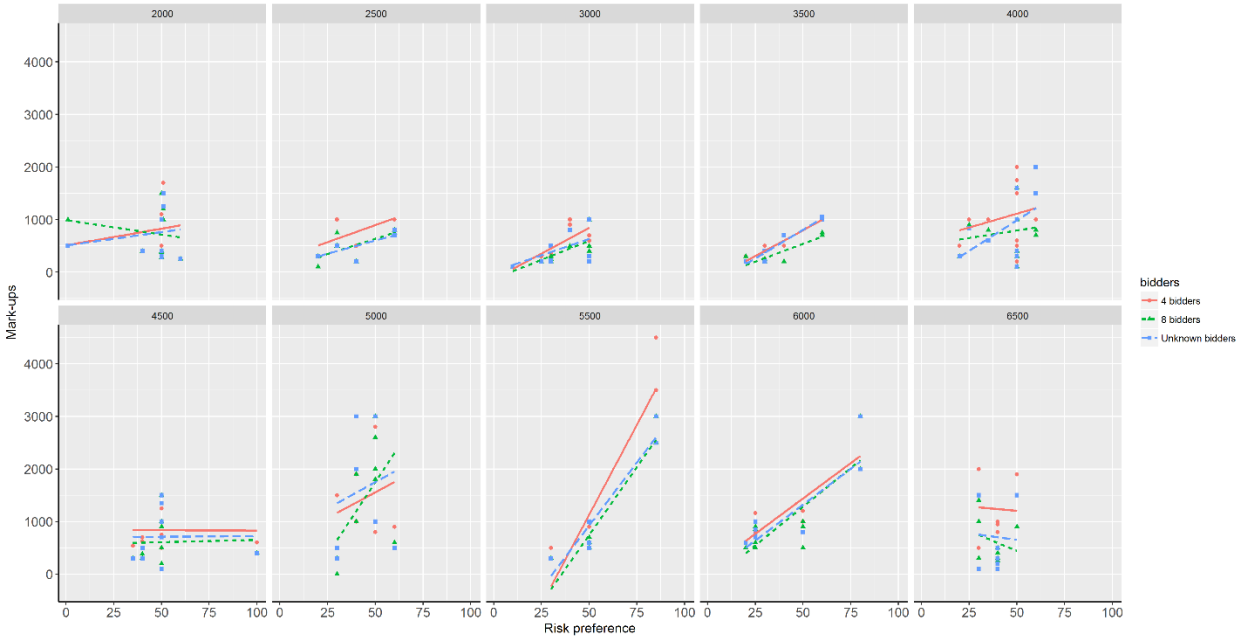

Table 1. Basic characteristics of participants

Characteristics	Categorization	Number	Percent
Age	20-30	58	34%

	30-40	100	58%
	40-50	9	5%
	>50	5	3%
Gender	Male	114	66%
	Female	58	34%
Marital status	Married	89	52%
	Unmarried	83	48%
Education background	Lower than bachelor degree	2	1%
	Bachelor degree	163	95%
	Higher than bachelor degree	7	4%
Income level	A=CNY 30000-80000	64	37%
	B=CNY 80000-130000	58	34%
	C=CNY 130000-180000	21	12%
	D=CNY 180000-230000	19	11%
	E>CNY 230000	10	6%
Work experience	10-15 years	84	49%
	15-20 years	57	33%
	20-25 years	22	13%
	>25 years	9	5%
Bid experience	With bid experience	86	50%
	Without bid experience	86	50%
Position	Senior manager	24	14%
	Middle project manager	74	43%
	Technical staff	74	43%

Table 2. Risk preference tests

No.	Risk preference test with known probability	
	Option A	Option B
1	Get CNY 1	Get CNY 100 with 50%
2	Get CNY 2	Get CNY 100 with 50%
3	Get CNY 3	Get CNY 100 with 50%
.....	……	……
100	Get CNY 100	Get CNY 100 with 50%

Table 3. Descriptive results

Variables	Mean	Std. Dev.	Min	Max
Risk preference (shifting point)	43.99	16.535	1	100
Risk preference (ratio)	0.88	0.33	0.02	2
Cost	4225.00	1380.556	2000	6500
Bid price (4 bidders)	5246.6	1798.648	2250	10000
Bid price (8 bidders)	5000.8	1693.197	2250	9000
Bid price (unknown no. of bidders)	5099.9	1738.808	2250	9000
Mark-ups (4 bidders)	1021.60	751.449	100	4500
Mark-ups (8 bidders)	775.80	672.236	0	3000
Mark-ups (unknown no of bidders)	874.90	730.400	100	3000

Table 4. Risk preference and bidding behavior in different scenarios

Variables	4 bidders		8 Bidders		Unknown bidders	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Risk preference	0.541*** (3.86)	.493*** (3.69)	0.507*** (3.54)	.430*** (3.58)	0.491*** (3.89)	.426*** (3.91)
Cost		.353*** (0.04)		.274*** (0.04)		.283*** (0.05)
Work experience		.551 (52.75)		.594 (51.18)		.538 (55.91)
Bid experience		-.107 (3.01)		-.228 (2.92)		-.234 (3.19)
Age		-.649 (49.82)		-.721 (48.33)		-.644 (52.80)
Gender		.003 (120.58)		-.022 (116.98)		-.046 (127.80)
Education		-.071 (272.18)		-.197 (264.05)		-.180 (288.45)
If married（1=Yes）		.219 (142.92)		.238 (138.66)		.172 (151.47)
Income		-.257 (71.87)		-.121 (69.72)		-.131 (76.168)
R^2	0.95	0.97	0.93	0.96	0.95	0.96

Note: Standard errors are shown in parentheses; * = p<0.1, ** = p<0.05, *** = p<0.01

Table 5. Mark-ups with different costs in different scenarios

Cost	4 bidders		8 bidders		Unknown bidders	
	Average mark-ups	Ratio (%)	Average mark-ups	Ratio (%)	Average mark-ups	Ratio (%)
Cost=2000	798	39.90	741	37.05	738	36.90
Cost=2500	729	29.14	486	19.43	471	18.86
Cost=3000	505	16.82	345	11.51	417	13.90
Cost=3500	657	18.78	443	12.65	650	18.57
Cost=4000	1075	26.88	771	19.29	903	22.57
Cost=4500	834	18.54	607	13.48	708	15.74
Cost=5000	1440	28.80	1420	28.40	1630	32.60
Cost=5500	1778	32.32	1233	22.42	1378	25.05
Cost=6000	1251	20.85	1075	17.92	1130	18.83

Cost=6500	1244	19.13	631	9.71	713	10.96

Note: Ratio=Average mark-ups/cost

Table 6. Risk preference (ratio) and bidding behavior in different scenarios

Variables	4 bidders		8 Bidders		Unknown bidders	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Risk preference	0.542*** (192.90)	0.493*** (184.58)	0.507*** (177.02)	0.430*** (179.07)	0.491*** (194.35)	.426*** (195.61)
Cost		0.353*** (.04)		0.274*** (.042)		.283*** (.045)
Work experience		.551 (52.75)		.594 (51.18)		.538 (55.91)
Bid experience		-.107 (3.01)		-.228 (2.92)		-.234 (3.19)
Age		-.649 (49.82)		-.721 (48.33)		-.644 (52.79)
Gender		.003 (120.58)		-.022 (116.98)		-.046 (127.79)
Education		-.071 (272.175)		-.197 (264.05)		-.180 (288.45)
If married（1=Yes）		.219 (142.92)		.238 (138.66)		.172 (151.47)
Income		-.257 (71.87)		-.121 (69.72)		-.131 (76.17)
R^2	0.94	0.95	0.95	0.95	0.94	0.93

Note: Standard errors are shown in parentheses; * = p<0.1, ** = p<0.05, *** = p<0.01