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Does Multi-Attribute Bidding in Public Construction Projects Prevent Corruption while Tenderers' Preferences are Open? A Study of China's Practice

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ABSTRACT

This paper establishes a method of supply-chain multi-attribute reverse auction. Presuming the tenderers' preference is open, the paper proposes a non-cooperative multi-attribute bidding game model about public construction projects and analyzes the bidding strategies of tenderers and bidders. Through the simulation of a case in China, we find that: (1) the more committed of the tenderers to construction quality and schedule, the greater benefits, enthusiasm in bidding, and tenderer's surplus; (2) the bidder's benefits have a U-shaped relationship respectively with the bidding quality and the construction period; and (3) the greater the bidder's construction quality and period cost coefficients, the smaller the tenderer's surplus. Such conclusions indicate, the improvement of the bidding rules or procedures can contribute to restricting the behavior of tenderer and bidder, furthermore reducing the corruption possibility of public construction projects.

Keywords: public construction projects, multi-attribute bidding, tenderers' preference, corruption

INTRODUCTION

The construction sector, whether privately or publicly financed, is characterized by potentially large rents and government intervention, which makes it vulnerable to corruption (Kyriacou, et al. 2015). Particularly, corruption in public construction or infrastructure projects is a perennial problem (Sikka and Lehman, 2015), especially in developing countries. When measured by ''perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests'' during the whole life-circle of project (Kaufmann et al. 2010; Andreas , et al. 2015), the perceived corruption in public construction is far more significant in Russia, Indonesia and India than that in Scandinavia and New Zealand (Andreas , et al. 2015),which is partly caused by continual economic growth and rapid urbanization worldwide (Transparency International 2006, 2008, 2011). In China, cases of corruption recorded in the public construction sector during 2013-2015, reported by the National Bureau of Corruption Prevention, increased from 15,010 rapidly to 46,400 cases which caused 16,700 relevant lawsuits (Ming Shan et al. 2015). On account of that, some countries even questioned the transparency and efficiency of the Asia Infrastructure Investment Bank (AIIB) (citation). China as well as other developing countries with rapid economic growth are facing a greater challenge in preventing corruption than the developed world due to the lack of sufficiently legislative and institutional support (Alutu 2007; Bowen et al. 2007a, b, 2012; Alutu, Udhawuve 2009; Ameh, Odusami 2010; Tabish, Jha 2011; Choudhry, Iqbal 2013; Le Y et al. 2014).

As solutions for corruption prevention, EU suggests to introduce surveillance which ''strengthens credibility so that government officials can be held responsible for the proper implementation of public procurement rules and regulations and the decisions they make in actual procurement practices. Such accountability requires a credible sanctioning system in case of violations of rules with adequate internal controls and audit procedures; a complaints system for bidders as well as appropriate administrative; and judicial review bodies attributed with the authority

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Contribution of this paper to the literature

- If the tenderers' preference is open, which means more transparency in public construction projects to some extent, the bidders are more likely to focus on improving their bidding strategies rather than bribery or other corruption behaviors. Such conclusions can help policymaker to perfect the bidding system of public construction projects and normalize the bidding behaviors of tenderers and bidders.
- The tenderer's preference coefficient will be truly informed of all bidding participants when we are formulating the multi-attribute bidding model about public construction projects.

to impose corrective measures'' (European Commission, 2013:260). In line with this recommendation, numerous studies have focused on examining the ethics-related aspects of corruption, particularly regarding bribery (Cleveland et al. 2009; Ehlermann-Cache 2007; Berrios 2006), highlighting how to improve the effectiveness of internal controls and monitoring practices via moral responsiveness and agency (Painter-Morland, 2011;Neu D. et al., 2013). If successful, these practices have the potentials to construct a disciplined and ethical subject whose behaviors make corruptive practices the exception rather than the norm. And, for these reasons, it is important to both understand and nurture the micro-practices of visibility **(**Neu D. et al. 2015**)**.

In China, as most of other countries, a series of measures has been put forward aiming at increasing transparency in the dealings of both construction firms and governments by, for example, empowering whistleblowers both in the public and private sectors through implementing appropriate policies and procedures (Sohail and Cavill 2008; Hardoon and Heinrich 2011). Unfortunately, although anti-corruption policies have already been proposed and employed in the public construction projects, the public construction is still the most corruptive industry recognized by the public. The severe situation of corruption in public construction projects has not been alleviated by far (Transparency International 2006, 2008, 2011), which causes the policy-maker to explore some complex measures to deal with the corruption in public construction projects, such as the adoption of ethical codes and related training programs for construction industry professionals (Le Y. et al. 2014; Tu, Tu, & Jhangr, 2016) and the acceptance of a debarment system used already in the European Union, whereby companies or individuals who are found to be guilty of corruption are prevented from participating in future construction projects (Jong et al. 2009). Besides, promoting competition is considered as a desirable policy in relation to bids for public sector construction projects (Ades, Di Tella 1999; Kenny 2009), especially when the links between natural resource endowments and corruption can be confirmed (Aslaksen 2009; Busse, Gro¨ning 2013; Sala-i-Martin, Subramanian 2013).

These recommended measures seem to shine a light on the possibility of discouraging and combating corruptive practices within the public construction projects, but their feasibility depends on the assumption that one could be ethical if there are appropriately designed internal controls and surveillance systems which give visibility to departures from the established norms (Neu D. et al. 2015). The rationality of this hypothesis in developing countries is doubtable especially when considering that government officials indulge in illicit activity and corruption primarily happens on the demand-side (Prem Sikka, Glen Lehman 2015; Wang, 2016). Thus, in contrast with theories which pay much attention to ethics, responsibility and internal control, some measures have been laid more emphasis on how to induce an efficient competition regulation/mechanism so as to squeeze the corruption space or minimize the probability of corruption.

As to public construction projects, efficient competition regulation/mechanism are in place regarding the auction or bidding procedures. There are two common rules: First-Price-Auction (FPA) and Right-of-First-Refusal (ROFR) (Karine Brisset, et al. 2015). In general bidders are slightly but significantly more aggressive under the ROFR than FPA. Furthermore, newcomers will bid similarly under both procedures (ROFR and FPA), and sellers exhibit the same degree of risk-aversion (Brisset and Maréchal 2014; Burguet R., Perry,M. 2009). This means it is possible for public sector to achieve the optimum gain by some effective bidding procedures various research has been done to the multi-attribute bidding, David et al. (2006) proposed a general multi-attribute auction (adverse bidding) model; Che(1993) formulated a two-dimensional multi-attribute auction (adverse bidding) model concerning bidding price and quality, and proposed three forms, i.e., first grading auction, second grading auction, and third grading auction, and Wang Hong et al. (2013) converted the bidder's quality information into the comprehensive quality index to solve the multi-dimensional information tender optimal mechanism based on maximization of social welfare. Huang He et al. (2008) assumes that the bidder bid respectively on quality and price, and then solve the winning problem using the tree structure. Viewing the tenderer's utility function as a linear function concerning quality and turn-key date, we can examine the supply-chain online multi-attribute adverse auction using the game theory (Zhou Xueguang et al. 2014), or extend the bidder's optimal bidding strategy under multi-attribute auction (Sun Yahui, Feng Yuqiang 2010).

However, in China, owing to the public sector's powerful influence, either FPA or ROFR (even during a multi-attribute bidding) is vulnerable to be manipulated by relevant practitioner in public construction projects, while

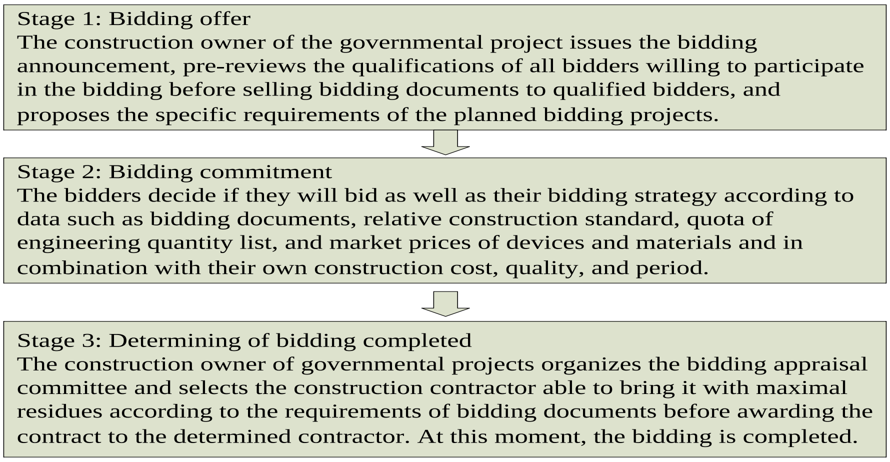

Figure 1. The process of public construction projects' bidding

the tenderers' preference is sealed. For example, the agents of public construction projects or their collusive partners will propose some irrational appraisal indicators which probably affect the justice of bidding during bid evaluation. At the same time, they can set some artificial bidding attributes so that they can manipulate the bidding procedure to select their favorite bidder. Furthermore, usually the bidding proposals are evaluated by key indicators, i.e., quality, construction period, and expenditures, which will result in some more invisible evaluation and increase the corruption probability during the bidding of public construction projects in China (He Huang, Zhipeng Li 2015). Hence, this paper will discuss: supposing the tenderers' preference is open, can we achieve balance among the bidding system which lead bidders to submit optimum proposal without any bribe or collusion? And how can we constrain the corruption by improving the rule or procedure of bidding in public construction projects?

Given the supply-chain multi-attribute adverse auction method, this paper firstly formulate a non-cooperative multi-attribute bidding game model of public construction projects based on David (2006) and Sun et al. (2010). Moreover, presuming the tenderers' preference is open this paper analyzes the bidding strategies of the tenderer and the bidder, verifying relative findings through an algorithm case of China in combination with Matlab simulation. Finally, we discuss whether the bidding rules or procedures will have an impact on the corruption probability of public construction projects.

PROPOSITION OF THE MODEL

Description of the Problems

At present, the construction owner or agent owner of public construction projects determines some project as a multi-attribute tender in China. As stipulated by the tender documents, the bidder's multi-attribute consists of quoted price, quality grade, and construction period. The tender process is composed of pre-examination of qualification documents, writing and examination of tender documents, issuance of tender bulletin (or tender invitation), pre-examination of qualification, sale of tender documents, field investigation, bidding preliminary meeting, writing of and submission of bidding documents, submission of the lowest bidding price for examination, opening of bidding, bidding appraisal, obtaining of bidding, and contract signing. The key time points consist of issuance of tender bulletin, submission of bidding documents, and determination of the successful bidder. Thus, the bidding process of the public construction projects can be viewed as a dynamic three-stage game between the owner and contractor. The specific game process is shown as in **Figure 1**. In the first stage, the construction owner issues the tender bulletin of some construction unit (item) such as the said project's construction site, scale, detailed demand standard, construction period, date of starting the construction and details of the list of engineering quantity to help the bidder to conduct evaluation and decide whether to participate in the bidding or not. In the second stage, the contractor decides if it should participate in the bidding as well as the bidding strategy based on the provided data information such as tender documents, construction standards, list of engineering quantity, market price for devices, materials and in combination with its own construction cost, quality, and construction period (Qing Quande et al. 2012). In the third stage, the construction owner or entrusted tenderer organizes a bidding appraisal committee to select and evaluate the bidders' bidding documents according to the requirements of the tender documents in order to select the best bidding document as the final bidding and grant the construction contract. Until now, the tender is completed.

Hypotheses

Based on the two-dimensional multi-attribute auction model concerning bidding price and quality constructed by Che (1993), we added a tender attribute, construction period with intention to formulate a more practical multi-attribute tender game model on public construction projects based on maximization of tenderer residuals and solve the model. Then, we analyzed the bidding strategy of the tenderer and bidder. For the sake of analysis, we propose the following hypotheses:

HA1 There are $n+1$ participants in the bidding of some public construction project, including 1 tenderer (owner) and n bidders, to be expressed as $N=\{0,1,\dots,n\}$, among which 0 represents the tenderer (owner or agent owner).

HA2 Suppose the longest construction period stipulated by the tenderer is T, and the type function Θ_i of bidder $i(i=1,\dots,n)$ is determined by its bidding quality q_i and construction period ahead of time t_i, both of which are private information, i.e., no one but the bidder himself knows them, while the owner and other bidder do not know their specific value. They are viewed as two mutually independent stochastic variables which are equally distributed in intervals $[Q_L,Q_S]$ and $[T_L,T_S]$, among which Q_L stands for the national lowest quality standard, Q_S for the highest quality standard all bidders may reach, T_L and T_S respectively for the top and bottom limits of the construction period ahead of time committed by the bidder. The distribution function and density are respectively expressed as $F(q_i)$, $G(t_i)$, $f(q_i)$, and $g(t_i)$.

HA3 The utility function brought by bidder i to the tenderer is $U=\alpha q_i^{b_1}+\beta(T-t_i)^{b_2}-p_i$ to be informed of all bidding participants. $q_i=\frac{q_i^0}{Q}$ stands for the bidding quality (among which q_i^0 stands for bidder i's committed bidding quality), T for the longest construction period contracted by the tender document, α and β respectively for the weight coefficients of quality and construction period, and $0<\alpha\leq 1$ and $0<\beta\leq 1$. When both α and β are 0, such bidding is traditionally single-attribute bidding; when both α and β are greater than 1, the tenderer value quality and construction period more than price, and this does not conform to the bidding practice, so α and β are valued to be greater than 0 but less than 1. b_1 and b_2 respectively stands for the tenderer's preference degree to project quality and construction period. When they are less than 1, it means that the tenderer prefers price, i.e., the tenderer prefers the tender offer's price. When they are 1, it means that the tenderer's utility has a linear relationship with them. When they are greater than 1, it means that the tenderer prefers project quality and construction period. It is obvious that $\alpha q_i^{b_1}-q_i^{k_1}>0, \beta(T-t_i)^{b_2}-(T-t_i)^{k_2}>0$. Otherwise, the cost at which the bidder improves its project quality and shortens its construction period is greater than its payment to the tenderer.

HA4 The construction cost of bidder i is a function of bidding project quality and construction period, i.e., $C_i=q_i^{k_1}+(T-t_i)^{k_2}$.

HA5 Participants in the bidding of the public construction projects game with complete information and bidders have symmetric information and thus have no chance of cooperating.

Modeling

It follows from HA3 that the utility function provided by bidders $i(i=1,\dots,n)$ to the tenderer can be expressed as:

$$U_i=\alpha q_i^{b_1}+\beta(T-t_i)^{b_2}-p_i \tag{1}$$

The profit of bidder i equals its offer minus the construction cost. In combination with HA5, the profit of bidder i can be expressed as:

$$\pi_i=p_i-q_i^{k_1}-(T-t_i)^{k_2} \tag{2}$$

Among which k_1 and k_2 are a constant and represents the unit cost coefficients of project quality and construction period when the bidder completes the construction task of its planned bidding project.

From the perspective of probability, every bidder participating in the bidding of public construction projects have some probability which can be expressed as $\mathrm{Pr}ob(q_i,t_i,U^*,n)$, indicating there are n bidders participating in the bidding and bidder i bids according to the (q_i,t_i) combination and brings the tenderer a probability with the maximal utility U^*. Hence, the bidder's expected profit can be expressed as:

$$\begin{aligned}&E(\pi_i)=\left[p_i-q_i^{k_1}-(T-t_i)^{k_2}\right]\cdot Prob(q_i,t_i,U^*,n)\\&S.t.\pi_i>0\end{aligned} \tag{3}$$

SOLUTION TO AND ANALYSIS OF THE DYNAMIC GAME

According to HA5, bidders have no chance of cooperating, i.e., there is no alliance or collusion among bidders. Therefore, game among participants in the bidding of public construction project is non-cooperative, and every bidder determines its bidding strategy according to its own cost, quality, and construction period.

Equilibrium Bidding Strategy

In the practice of the bidding of public construction projects, every bidder has a full understanding of the game process before it selects a bidding strategy. At every stage, only one participant has over one space of action, and all other participants do not take any actions. Thus, the multi-attribute bidding of public construction projects is a three-stage complete and perfect dynamic game, and the sub-game perfect Nash equilibrium can be solved by Backwards Induction.

Let us first consider stage three in the game of the bidding of public construction projects. The sub-game perfect Nash equilibrium strategy enables the tenderer to select the bidder able to bring the maximal utility. Suppose bidder i is able to bring the maximal utility to the tenderer, i.e., the bidding strategy of bidder i meets the following:

$$U_i = MaxU_j(j = 1, \dots, n) = \alpha q_i^{b_1} + \beta(T - t_i)^{b_2} - p_i \tag{4}$$

In stage two, every bidder participating in the bidding of the public construction project determines such data as quota and the market price of devices according to relative construction standard and list of construction quantity and selects a bidding strategy capable of maximizing its profit in combination with its own construction cost, quality, and construction period. The bidding of the bidder able to win the bidding can bring the bidder the maximal utility, i.e., it meets Equation (4). Hence, the bidding strategy simultaneously meeting the above two conditions is the sub-game perfect Nash equilibrium, i.e., the bidder's bidding strategy is to maximize Equation (3).

It follows from HA2 that the bidder's type function is determined by quality q_i and construction period t_i, to be expressed as $\Theta(q_i, t_i)$. The utility brought by bidder i to the tenderer is related to bidding price, quality, and construction period; As the bidder's offer is a function of its quality and construction period, the utility brought by the bidder to the tenderer can be viewed as the score for the bidder's bidding offer. Hence, s_i and Θ_i can respectively stand for the bidding score and the type function which meets:

$$s_i = \alpha q_i^{b_1} + \beta(T - t_i)^{b_2} - p_i \tag{5}$$

$$\Theta_i = \left(\alpha q_i^{b_1} - q_i^{k_1}\right) + [\beta(T - t_i)^{b_2} - (T - t_i)^{k_2}] \tag{6}$$

It also follows from HA2 that the distribution functions of the construction quality and period of bidder i's planned project are $F(q_i)$ and $G(t_i)$, and the distribution function $H(\Theta_i)$ represents the distribution function of the bidder's type function value. Meanwhile, we define the bidder with the highest construction quality and shortest construction period as the best bidder, to be expressed as $\Theta_h = (q_h, t_h)$; and we also define the bidder with the lowest construction quality and longest construction period as the poorest bidder, to be expressed as $\Theta_l = (q_l, t_l)$. Obviously, the higher the construction quality and the shorter the construction period, the better the type of bidder will be. Thus, $H(\Theta_i)$ is a function greater than 0 and continuously increasing with the bidder's type function Θ_i.

Hence, we can obtain the bidder's optimal equilibrium strategy by putting Equation (5) into Equation (1):

$$U_i = s_i = Maxs_j(j = 1, \dots, n) \tag{7}$$

And we can obtain bidder i's optimal equilibrium strategy by putting Equations (5) and (6) into Equation (3):

$$MaxE\left(\pi_i(\Theta_i, s_i)\right) = (\Theta_i - s_i)\mathrm{Pr}ob(q_i, t_i, U^*, n) \tag{8}$$

The Sub-Game Perfect Nash Equilibrium

Suppose the bidding price of the bidding decision of bidder i with a type function of Θ_i is determined by some function of the quality and construction period of its planned project, so the bidder's offer can be supposed to be determined by its bidding function B i.e., the offer of bidder j is determined by $B(\Theta_j)$. It is obvious that B is a monotone increasing function. Hence, a bidder with a better type can bring greater utility to the tenderer and its competence is stronger, so its bidding offer can have a high score. If the bidder wins the bidding, its offer is supposed to meet $S_i > S_j, (j \neq i, j = 1,2,3, \dots, n)$. Therefore, if the offer of bidder i has a score of S_i, bidder i's probability of winning the bidding is that of all other bidders whose scores of bidding offers meet $B(\Theta_j) < s_i$. Thus, it holds that $\mathrm{Pr}ob(q_i, t_i, U^*, n) = \left[H\left(B^{-1}(s_i)\right)\right]^{n-1}$, among which $B^{-1}(\cdot)$ is an reverse function of $B(\cdot)$. Hence, the expected profit of bidder i whose score of bidding offer is s_i can be expressed as:

$$\pi_i(\Theta_i, s_i) = (\Theta_i - s_i)\left[H\left(B^{-1}(s_i)\right)\right]^{n-1} \tag{9}$$

In terms of bidder i, its sub-game perfect Nash equilibrium is to select the optimal bidding offer score s_i^*. Hence, let us first get the derivation of the two ends of Equation (9) and suppose it to be 0, i.e.,

$$\left.\frac{\partial \pi_i}{\partial s_i}\right|_{s_i=s_i^*} = 0 \tag{10}$$

Then get the derivation of Θ_i from Equation (9) and we can obtain:

$$\frac{\partial \pi_i}{\partial \Theta_i} = \left[H\left(B^{-1}(s_i)\right)\right]^{n-1} \tag{11}$$

Besides, get the derivation of Θ_i with $\pi_i(\Theta_i, s_i)$ and we can obtain

$$\frac{d\pi_i}{d\Theta_i} = \frac{\partial \pi_i}{\partial \Theta_i} + \frac{\partial \pi_i}{\partial s_i} \cdot \frac{ds_i}{d\Theta_i} \tag{12}$$

By putting $s_i = s_i^*$, Equation (10) , and Equation (11) into Equation (12),we can obtain:

$$\left.\frac{d\pi_i}{d\Theta_i}\right|_{s_i=s_i^*} = \left.\frac{\partial \pi_i}{\partial s_i}\right|_{s_i=s_i^*} = \left[H\left(B^{-1}(s_i)\right)\right]^{n-1} \tag{13}$$

According to HA5, all bidders have symmetric information, and the bidding function B of all bidding participants meets the condition of maximizing expected profits in Equation (9), so bidders with the same bidding offer scores have the same type, i.e., under the condition of the sub-game perfect Nash equilibrium, $s_i = B(\Theta_i)$. Put it into Equation (13) and we can obtain:

$$\left.\frac{d\pi_i}{d\Theta_i}\right| = [H(\Theta_i)]^{n-1} \tag{14}$$

Get the derivation of Θ_i in the two ends of Equation (14) and we can obtain:

$$\pi_i = \int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi + \pi_i(\Theta_L) \tag{15}$$

It is obvious that $\pi_i(\Theta_L) = 0$. Thus, the bidder with the poorest type is unlikely to win the bidding, and its payment is 0. Put it into Equation (15) and we can obtain:

$$\pi_i = \int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi \tag{16}$$

Put $s_i = B(\Theta_i)$ into Equation (9) and we can obtain:

$$\pi_i(\Theta_i, s_i) = (\Theta_i - s_i)[H(\Theta_i)]^{n-1} \tag{17}$$

Finally, put Equation (16) into Equation (17) and we can obtain the bidders' bidding offer strategy:

$$p = q_i^{k_1} + (T - t_i)^{k_2} + \frac{\int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi}{[H(\Theta_i)]^{n-1}} \tag{18}$$

It follows from Equation (18) that the optimal bidding offer strategy consists of two parts: the bidder's construction cost of completing the planned bidding project $q_i^{k_1} + (T - t_i)^{k_2}$ and the above-average returns brought by the bidder's type advantage $\frac{\int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi}{[H(\Theta_i)]^{n-1}}$, and its optimal offer strategy is a function of its cost.

Proposition1 In the non-cooperative game model about public construction project bidding, the bidders have a sub-game perfect Nash equilibrium strategy (p^*, q_i^*, t_i^*), among which p^* is Equation (18) and q_i^*, t_i^* represents its own real value.

Proof: Suppose bidder i has a type function of $\Theta_i = (q_i, t_i)$ and pretends to bid according to type function $\Theta_i' = (q_i', t_i')$, and other $n-1$ bidders provide bidding offers according to the strategy in Equation (18). Their type function is Θ_i whose condition for participating in bidding is the payment obtained by bidding according to its type function Θ_i' equals that obtained by bidding according to other type functions Θ_i' (As the bidder is rational, the payment he obtains when he pretends to bid according to type function Θ_i' is certainly greater than that he obtains when he bids according to other type functions Θ_i. $p^*(q_i^*, t_i^*)$ is an equilibrium solution, so bidders i can maximize its payment when he bids according to this strategy. Hence, the payment the bidder can obtain when he pretends to bid according to type function Θ_i' equals that when he participates in bidding according to the real type function), i.e.,

$$\frac{\partial \pi_i(\Theta_i, \Theta_i')}{\partial \Theta_i'} = 0 \tag{19}$$

When the bidder having a type function of Θ_i bids when the type function pretends to be Θ_i', the expected payment he can obtain is:

$$\pi_i(\Theta_i,\Theta_i') = \left[p_i - q_i^{k_1} + (T-t_i)^{k_2}\right] \cdot [H(\Theta_i')]^{n-1} \tag{20}$$

Put Equation (1) into Equation (20) and we can obtain:

$$\pi_i(\Theta_i,\Theta_i') = \left[\alpha q_i^{b_1} + \beta(T-t_i)^{b_2} - U_i(\Theta_i') - q_i^{k_1} + (T-t_i)^{k_2}\right] \cdot [H(\Theta_i')]^{n-1} \tag{21}$$

Put Equation (6) into Equation (21) and we can obtain:

$$\pi_i(\Theta_i,\Theta_i') = \Theta_i \cdot [H(\Theta_i')]^{n-1} - U_i(\Theta_i') \cdot [H(\Theta_i')]^{n-1} \tag{22}$$

Get the partial derivative of Θ_i' in the two ends of Equation (22) and we can obtain:

$$\frac{\partial \pi_i}{\partial \Theta_i'} = \Theta_i \cdot \frac{\partial [H(\Theta_i')]^{n-1}}{\partial \Theta_i'} - \frac{\partial [U_i(\Theta_i') \cdot [H(\Theta_i')]^{n-1}]}{\partial \Theta_i'} \tag{23}$$

When bidder i having a type function of Θ_i bids when the type function pretends to be Θ_i', the expected surplus he can obtain is:

$$S(\Theta_i') = U(\Theta_i') \cdot [H(\Theta_i')]^{n-1} \tag{24}$$

It follows from Equation (1) that:

$$U(\Theta_i') = \alpha(q_i')^{b_1} + \beta(T-t_i')^{b_2} - p_i' \tag{25}$$

Put Equation (18) into Equation (25) and we can obtain:

$$U(\Theta_i') = \Theta_i' + \frac{\int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi}{[H(\Theta_i)]^{n-1}} \tag{26}$$

Put Equation (26) into Equation (24) and we can obtain:

$$S(\Theta_i') = \Theta_i' \cdot [H(\Theta_i')]^{n-1} + \int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi \tag{27}$$

Get the derivation of Θ_i' in the two ends of Equation (25) and we can obtain:

$$\frac{\partial S(\Theta_i')}{\partial \Theta_i'} = \Theta_i' \cdot \frac{\partial [H(\Theta_i')]^{n-1}}{\partial \Theta_i'} \tag{28}$$

Put Equation (28) into Equation (23) and we can obtain:

$$\frac{\partial \pi_i}{\partial \Theta_i'} = (\Theta_i - \Theta_i') \cdot (n-1) \cdot [H(\Theta_i')]^{n-2} \cdot H'(\Theta_i') \tag{29}$$

In Equation (29), the bidder's type distribution function is an increasing function greater than 0, i.e. $H(\Theta_i') > 0, H'(\Theta_i') > 0$ plus $(n-1) > 0$, so Equation (29) meeting Equation (18) can only value to be $\Theta_i = \Theta_i'$, and the bidder's optimal bidding strategy is excessive, i.e., it meets the condition of sub-game perfect Nash equilibrium.

Nature of Bidder's Bidding Strategy

Proposition 2 Public construction projects preferred by open tenderers belong mostly to the bidding game model. The bidder's profit has a U–shape relationship with its bidding quality and construction period, i.e., when its bidding quality and construction period ahead of time exceed a certain point, the bidder's profit is respectively an increasing function of its bidding quality and construction period. Before reaching this point, the bidding quality and construction period ahead of time have a decreasing marginal profit.

Proof: Suppose in the bidding of public construction projects, the committed bidding quality of bidder i is $q_i = \frac{q_i^0}{Q_L}$ and the construction period ahead of time is t_i. Under the sub-game perfect Nash equilibrium, bidder i provides his bidding offer according to Equation (18). Put Equation (18) into Equation (3) and we can obtain the expected payment of bidder i:

$$E(\pi_i) = \int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi \tag{30}$$

Get the partial derivation of q_i in the two ends of Equation (30) and we can obtain:

$$\frac{\partial E(\pi_i)}{\partial q_i} = \left(\alpha b_1 q_i^{b_1-1} - k_1 q_i^{k_1-1}\right) \cdot [H(\Theta_i)]^{n-1} \tag{31}$$

$H(\Theta_i) > 0$ (when $H(\Theta_i) = 0$, the probability of bidder i's winning the bid is 0. Thus, we do not consider such situation), so $H(\Theta_i) > 0$.

When $k_1 \geq b_1$, rational bidder i will give up its bidding. Its quality cost is greater than the tenderer's quality utility, so $k_1 < b_1$.

1) When $k_1 = 1$,

$$\begin{cases} q_i > (ab_1)^{\frac{1}{1-b_1}}, \partial E(\pi_i) > 0 \\ q_i < (ab_1)^{\frac{1}{1-b_1}}, \partial E(\pi_i) < 0 \end{cases} \tag{32}$$

2) When $k \neq 1$,

$$\begin{cases} q_i > (k_1\alpha^{-1}b_1^{-1})^{\frac{1}{b_1-k_1}}, \dfrac{\partial E(\pi_i)}{\partial q_i} > 0 \\ q_i = (k_1\alpha^{-1}b_1^{-1})^{\frac{1}{b_1-k_1}}, \dfrac{\partial E(\pi_i)}{\partial q_i} = 0 \\ q_i < (k_1\alpha^{-1}b_1^{-1})^{\frac{1}{b_1-k_1}}, \dfrac{\partial E(\pi_i)}{\partial q_i} < 0 \end{cases} \tag{33}$$

Get the partial derivation of t_i in the two ends of Equation (30) and we can obtain:

$$\frac{\partial E(\pi_i)}{\partial q_i} = (-\beta b_2(T - t_i)^{b_2-1} + k_2(T - t_i)^{k_2-1}) \cdot [H(\Theta_i)]^{n-1} \tag{34}$$

Likewise, when $k_2 \geq b_2$, rational bidder i will give up its bidding. Its construction period cost is greater than the tenderer's quality utility, so $k_2 < b_2$.

3) When $k_2 = 1$,

$$\begin{cases} t_i > T - (\beta b_2)^{\frac{1}{1-b_2}}, \dfrac{\partial E(\pi_i)}{\partial q_i} > 0 \\ t_i < T - (\beta b_2)^{\frac{1}{1-b_2}}, \dfrac{\partial E(\pi_i)}{\partial q_i} < 0 \end{cases} \tag{35}$$

4) When $k_2 \neq 1$,

$$\begin{cases} t_i < T - (\beta b_2 k_2^{-1})^{\frac{1}{k_2-b_2}}; \dfrac{\partial E(\pi_i)}{\partial q_i} > 0 \\ t_i = T - (\beta b_2 k_2^{-1})^{\frac{1}{k_2-b_2}}; \dfrac{\partial E(\pi_i)}{\partial q_i} = 0 \\ t_i > T - (\beta b_2 k_2^{-1})^{\frac{1}{k_2-b_2}}; \dfrac{\partial E(\pi_i)}{\partial q_i} < 0 \end{cases} \tag{36}$$

Hence, the tenderer's profit relationships with its bidding quality are as follows: (1) when $k_1 = 1$ and $q_i > (ab_1)^{\frac{1}{1-b_1}}$, the tenderer's profit is an increasing function of its quality; when $q_i < (ab_1)^{\frac{1}{1-b_1}}$, the tenderer's profit is a decreasing function of its quality. (2) when $k \neq 1$ and $q_i > (k_1\alpha^{-1}b_1^{-1})^{\frac{k_1-1}{b_1-1}}$, the tenderer's profit is an increasing function of its quality; when $q_i < (k_1\alpha^{-1}b_1^{-1})^{\frac{k_1-1}{b_1-1}}$, the tenderer's profit is a decreasing function of its quality.

The tenderer's profit relationships with its construction period are as follows: (1) when $k_2 = 1$ and $t_i > T - (\beta b_2)^{\frac{1}{1-b_2}}$, the tenderer's profit is an increasing function of its construction period ahead of time; when $t_i < T - (\beta b_2)^{\frac{1}{1-b_2}}$, the tenderer's profit is a decreasing function of its construction period ahead of time. (2) when $k_2 \neq 1$ and $t_i < T - (\beta b_2 k_2^{-1})^{\frac{b_2-1}{k_2-1}}$, the tenderer's profit is a decreasing function of its construction period ahead of time; when $t_i > T - (\beta b_2 k_2^{-1})^{\frac{b_2-1}{k_2-1}}$, the tenderer's profit is an increasing function of its construction period ahead of time. In other words, after its bidding quality and construction period ahead of time exceed a certain point, the bidder's profits are respectively an increasing function of its quality and construction period ahead of time, i.e., bidders with a better bidding type can show their competitive advantages and obtain greater profits; while before reaching the point, the bidding quality and construction period ahead of time have a decreasing marginal profit, a conclusion slightly different from Zhou(2011). This means that during the bidding practice of public construction projects, the tenderer must pay the corresponding additional expense to bidders when its requirements for the quality and construction period ahead of time exceed the national qualification standard.

Deduction 1 Public construction projects preferred by open tenderers belong mostly to the multi-attribute bidding model. Thus, the greater the preference coefficient of the tenderer's committed bidding quality and construction period ahead of time, the greater the bidders' profits.

Proof: Get the derivation of b_1 in the two ends of Equation (30) and we can obtain:

$$\frac{\partial \pi_i}{\partial b_1} = \begin{cases} \alpha q_i^{b_1} \cdot \ln q_1 \cdot [H(\Theta_i)]^{n-1} > 0, (q_i > 1) \\ 0, (q_i = 1) \end{cases} \tag{37}$$

It follows from Equation (37) that the bidder's profit is an increasing function of the tenderer's quality preference coefficient (it is obvious that $q_i > 1$, because the rational bidder's committed bidding quality is better than the lowest national quality standard when it bids adopting the multi-attribute).

Likewise, get the derivation of b_2 in the two ends of Equation (30) and we can obtain:

$$\frac{\partial E(\pi_i)}{\partial q_i} = \begin{cases} \beta(T - t_i)^{b_2} \cdot \ln(T - t_i) \cdot [H(\Theta_i)]^{n-1} > 0, (t_i < T - 1) \\ 0, (t_i = T - 1) \end{cases} \tag{38}$$

It follows from Equation (38) that the bidder's profit is an increasing function of the tenderer's construction period preference coefficient (it is obvious that $t_i < T - 1$, because the rational bidder's committed construction period ahead of time is often greater than 1 day during the bidding practice of public construction projects).

To sum up, the greater the preference coefficients of the tenderer's committed quality and construction period ahead of time, the greater the bidder's profit. Such conclusion seems contradictory to Proposition 2. But when the preference coefficients of the tenderer's committed quality and construction period ahead of time are big enough, the bidder's committed quality and construction period ahead of time will certainly exceed the minimal point in Proposition 2. Hence, deduction 1 is not contradictory to Proposition 2. In fact, they are consistent.

Nature of the Tenderer's Surplus

Proposition 3 During the bidding of public construction projects preferred by open tenderers, the bidders' residual utilities have a U–shape relationship with their bidding quality and construction period if all bidders bid according to Equation (18), i.e., the bidders' surplus is an increasing function of their bidding quality and construction period when the bidding quality and construction period exceed a certain point, while the bidders' surplus is a decreasing function of their bidding quality and construction period before the bidding quality and construction period reach the said point.

Proof: Put Equation (18) into Equation (1) and we can obtain the tenderer's consumer surplus:

$$U_i = \left(\alpha q_i^{b_1} - q_i^{k_1}\right) + [\beta(T - t_i)^{b_2} - (T - t)^{k_2}] - \frac{\int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi}{[H(\Theta_i)]^{n-1}} \tag{39}$$

Get the partial derivation of q_i in the two ends of Equation (39) and we can obtain:

$$\frac{\partial U_i}{\partial q_i} = (n-1) \cdot (\alpha b_1 q_i^{b_1 - 1} - k_1 q_i^{k-1}) \cdot H'(\Theta_i) \cdot \frac{\int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi}{[H(\Theta_i)]^{n-1}} \tag{40}$$

$H(\Theta_i)$>0, $H'(\Theta_i) > 0$ (when $H(\Theta_i) = 0$, the probability of bidder i of winning the bidding is 0, so we do not consider it), so:

$$\begin{cases} q_i > (k_i \alpha^{-1} b_1^{-1})^{\frac{1}{b_1 - k_1}}, \dfrac{\partial U_i}{\partial q_i} > 0 \\ q_i = (k_i \alpha^{-1} b_1^{-1})^{\frac{1}{b_1 - k_1}}, \dfrac{\partial U_i}{\partial q_i} = 0 \\ q_i < (k_i \alpha^{-1} b_1^{-1})^{\frac{1}{b_1 - k_1}}, \dfrac{\partial U_i}{\partial q_i} < 0 \end{cases} \tag{41}$$

Likewise, get the derivation of t_i in the two ends of Equation (39) and we can obtain:

$$\frac{\partial U_i}{\partial t_i} = (n-1) \cdot (-\beta b_2 (T - t_i)^{b_2 - 1} + k_2 (T - t_i)^{k_2 - 1}) \cdot H'(\Theta_i) \cdot \frac{\int_{\Theta_L}^{\Theta_i} [H(\xi)]^{n-1} d\xi}{[H(\Theta_i)]^{n-1}} \tag{42}$$

So,

$$\begin{cases} t_i < T - (\beta b_2 k_2^{-1})^{\frac{1}{k_2 - b_2}}; \dfrac{\partial U_i}{\partial q_i} > 0 \\ t_i = T - (\beta b_2 k_2^{-1})^{\frac{1}{k_2 - b_2}}; \dfrac{\partial U_i}{\partial q_i} = 0 \\ t_i > T - (\beta b_2 k_2^{-1})^{\frac{1}{k_2 - b_2}}; \dfrac{\partial U_i}{\partial q_i} < 0 \end{cases} \tag{43}$$

To sum up, the bidder's surplus is an increasing function of its bidding quality and construction period ahead of time when its committed bidding quality and construction period ahead of time exceeds a certain point, while the bidder's surplus is a decreasing function of its bidding quality and construction period ahead of time before its committed bidding quality and construction period ahead of time reach the said point.

Deduction 2 The greater the coefficient of the bidder's construction quality and construction period cost, the smaller the bidder's surplus.

Proof: Get the partial derivation of k_1 and k_2 in the two ends of Equation (39) and we can obtain:

$$\frac{\partial U_i}{\partial k_1}=\begin{cases}-(n-1)\cdot q_i^{k_1}\cdot \ln q_i\cdot H'_{k_1}(\Theta_i)\cdot\dfrac{\int_{\Theta_L}^{\Theta_i}[H(\xi)]^{n-1}d\xi}{[H(\Theta_i)]^{n-1}}<0,(q_i>1)\\ 0,(q_i=0)\end{cases}\tag{44}$$

$$\frac{\partial U_i}{\partial k_2}=\begin{cases}-(n-1)\cdot (T-t)^{k_1}\cdot \ln(T-t_i)\cdot H'_{k_2}(\Theta_i)\cdot\dfrac{\int_{\Theta_L}^{\Theta_i}[H(\xi)]^{n-1}d\xi}{[H(\Theta_i)]^{n-1}}<0,(t_i<T-1)\\ 0,(t_i=T-1)\end{cases}\tag{45}$$

Hence, the tenderer's consumer surplus is a decreasing function of the bidder's construction quality and construction period cost coefficients.

Deduction 3 When public construction projects adopt multi-attribute bidding, the greater the preference coefficient of the tenderer's committed bidding quality and construction period ahead of time, the greater its bidding surplus.

Proof: Get the partial derivation of b_1 and b_2 in the two ends of Equation (39) and we can obtain:

$$\frac{\partial U_i}{\partial b_1}=\begin{cases}(n-1)\cdot H'(\Theta_i)\cdot \alpha q_i^{b_1}\cdot ln q_i\cdot\dfrac{\int_{\Theta_L}^{\Theta_i}[H(\xi)]^{n-1}d\xi}{[H(\Theta_i)]^{n}}>0,(q_i>1)\\ 0,(q_i=1)\end{cases}\tag{46}$$

$$\frac{\partial U_i}{\partial b_2}=\begin{cases}(n-1)\cdot H'(\Theta_i)\cdot \beta(T-t_i)^{b_2}\cdot \ln(T-t_i)\cdot\dfrac{\int_{\Theta_L}^{\Theta_i}[H(\xi)]^{n-1}d\xi}{[H(\Theta_i)]^{n}}>0,(t_i<T-1)\\ 0,(t_i=T-1)\end{cases}\tag{47}$$

Hence, the tenderer's surplus is an increasing function of its committed bidding quality and construction period cost coefficients, i.e., the greater the preference coefficient of the tenderer's project quality and construction period, the greater its consumer surplus.

Participants' Optimal Strategy

Proposition 4 Participants in the multi-attribute bidding game of public construction projects are as follows: the bidders bid according to their real construction quality and construction period level and their bidding offers are shown in Equation (18), while the tenderer determine the winner according to the optimal combination of the bidders' bidding construction quality and construction period.

Proof: It follows from Proposition 1 that the bidder's optimal bidding game strategy is to bid according to its real construction quality and construction period and its bidding offer is shown in Equation (18). It also follows from Proposition 3 that bidders with a higher construction quality and bigger construction period ahead of time can bring greater bidding surplus to the tenderer. Hence, the tenderer tends to determine the winner according to the optimal combination of the bidders' bidding quality and construction period.

Therefore, during equilibrium, the bidder's optimal strategy is to provide bidding offer, according to Equation (18) and bid according to its construction quality and construction period. Such bidding manner helps the tenderer to determine the winner according to the performance/price ratio of the bidders' bidding and is thus contributive to improve the public construction projects' bidding efficiency. The reason is that the tenderer can determine the contractor of public construction projects according to the optimal combination of bidding quality, construction period, and price and the bidder with better bidding quality and shorter construction period can not only improve the tenderer's consumer surplus but also improve its own profit. Consequently, some technologically complicated projects' adopting multi-attribute bidding helps to improve the utilities of both the tenderer and the bidders and thus realize the win-win objective.

ALGORITHM VERIFICATION

In this paper the model is formulated on the basis of the operation pattern of China's public construction projects by means of applying some survey data to a simulation analysis. On one hand, the use of perception-based corruption data has been criticized because they do not correlate well with measures of reported corruption experience, which are typically drawn from survey questions about asking individuals if they have paid a bribe (Heywood 2015; Treisman 2015). On the other hand, data on reported or paid corruption may also be biased insofar as ''questions are politically sensitive, personally embarrassing or could lead to criminal sanctions''. That is, surveys of fraud or underreport bribery incidents typically cannot respond to these types of questions at all (Heywood 2015; Jensen, Rahman 2015). Therefore, this paper turns to practical data collected through relevant administrative bureaus in China to verify this model.

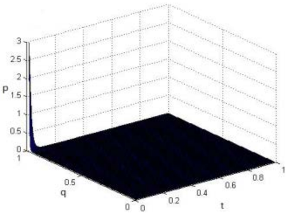

Figure 2. The relationship between bidding offer and construction period and quality

In accordance with *the Bidding Law of the People's Republic of China*, the contractors of government construction projects must be determined through bidding. At the same time, in order to prevent manipulation of bidding process as well as improve the transparency of public construction project bidding process, the bidding must be conducted by intermediary agents who have good qualification and authorized certification. Furthermore, under the legal framework most local governments in China established administrative departments of the government project bidding which assist in the oversight and management of public construction project bidding and the establishment of corresponding data file or database. On this background, this paper chooses the bidding data of public construction projects from 6 provinces' administrative departments in China through their management databases. These data formed from 2013 to 2015 covering the whole bidding process of public construction projects within the certain 6 provinces (Sichuan, Chongqing, Guangdong, Liaoning, Shanxi and Jiangxi). Based on these data we can extract the characteristics of the tender attributes, the tenderers' preference and the bidders' competence in cost and construction period control. With the characteristics we can simulate and verify the models as mentioned above.

After obtaining the initial data, we screen these data by following criteria: i. data should come from the large-scale public construction projects, marking in 100 million Yuan or above, due to its potential corruption space; ii. projects bidding conducted by intermediary agents with A Certificate, and conserved in complete documents, files or records of multiple attribute evaluation process, especially the management capacity of bidders; iii. in the bidding process, the tenders explicitly express their preference of quality and construction period through bidding meeting, the project instruction or project technical standards and other documents. Through the screening, we finally got 243 records. In these records, the weight coefficient of average quality and construction period of the tenders is $\alpha = 0.6, \beta = 0.5$ respectively, and the average quality of the lowest standard bidding is $Q = 0.3$. Given the longest construction period $T = 1$, the tender's public preference coefficient of average quality and construction period is $b_1 = 2.2, b_2 = 1.9$ respectively.

Among the 243 projects, the number of average bidders per project is $n = 5$. The coefficients of bidder's average quality and construction period are $k_1 = 1.5, k_2 = 1.2$ respectively. According to the above assumptions, the bidder's quality q_i^0 and construction period t_i conforms to uniform distribution at interval (0,1). On the basis of these data, we can discuss the relationship between the variables in the model.

(1) The relationship between bidding price and construction period and quality

It follows from Equation (18) that the bidding price of bidder i can be expressed as:

$$p_i = \left(\frac{q_i^0}{0.3}\right)^{1.5} + \left(\frac{1}{t_i^0}\right)^{1.2} + \frac{\int_0^{\Theta_i}[H(\xi)]^{n-1}d\xi}{[H(\Theta_i)]^{n-1}} \tag{48}$$

The figure about the relationship between the bidder's bidding offer and quality and construction period can be drawn from Equation (48) using *Matlab* as follows:

It follows from **Figure 2** that the bidder's bidding price rises drastically when the bidding quality or construction period ahead of time is close to the limit point (i.e., the quality is close to the highest quality grade and the construction period ahead of time close to the shortest construction period), because the bidder needs to improve its bidding offer to make up the engineering cost at the limit point, a finding consistent with the real situations.

(2) The relationship between the tenderer's surplus and bidding quality and construction period

Figure 3 about the relationship between the tenderer's surplus and bidding quality and construction period can be drawn using *Matlab* according to Equation (39) and data in the algorithm case.

The shape of **Figure 3** seems inconsistent with conclusions of Proposition 3, but we can get $\frac{\partial U_i}{\partial q_i} < 0$ by putting given data in the case into Equation (41), indicating that the tenderer's surplus decreases with the bidding quality; likewise, we can get $\frac{\partial U_i}{\partial t_i} < 0$ by putting given data in the case into Equation (43), indicating that the tenderer's surplus decreases with the construction period ahead of time. **Figure 3** only shows the decreasing part of the relationship between the tenderer's surplus and bidding quality and construction period. Thus, there is no contradiction.

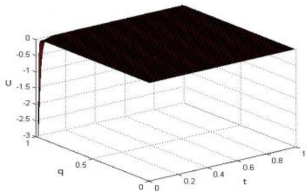

Figure 3. The relationship between the tenderer's surplus and bidding quality and construction period

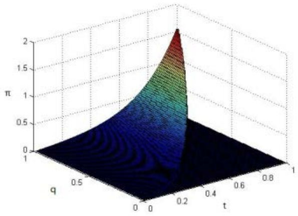

Figure 4. The relationship between the bidder's profit and bidding quality and construction period

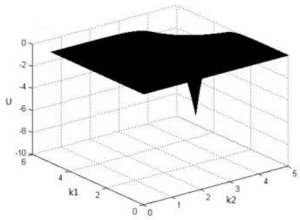

Figure 5. The relationship between the tenderer's surplus and the bidder's bidding quality and construction period cost

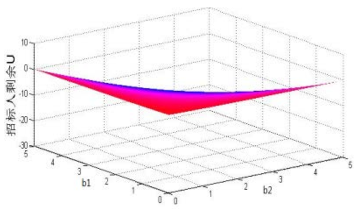

Figure 6. The relationship between the tenderer's surplus and the bidder's bidding quality and construction period cost

(3) The relationship between the bidder's profit and bidding quality and construction period

Figure 4 can be drawn using *Matlab* according to Equation (30) and data in the algorithm case. It follows from **Figure 4** that the bidder's additional profit from shortening the construction period is much greater than from improving the quality.

(4) The relationship between the tenderer's surplus and the bidder's bidding quality and construction period cost

Figure 5 about the relationship between the tenderer's surplus and the bidder's bidding quality and construction period cost can be drawn using *Matlab* according to Equation (39) and data in the algorithm case. The result is completely consistent with conclusions of deduction 2.

(5) The relationship between the tenderer's surplus and the bidder's preference coefficients of bidding quality and construction period cost

Figure 6 about the relationship between the tenderer's surplus and the bidder's bidding quality and construction period cost can be drawn using *Matlab* according to Equation (39) and data in the algorithm case. The result is consistent with conclusions of deduction 3.

CONCLUSIONS

Public construction projects substantially account for a considerable share of the government expenditures in China. However, owing to lack of transparency, most of the biddings in public construction projects are decided on a discretionary basis. In many cases, public officials prefer the favorite bidders in order to share the corruption benefits with them (He Huang, Zhipeng Li 2015). Even in cases that there are no bribery or collusion, some particular tenderers(generally the government's staffs or its agents) will manipulate the bidding to gain markups from asymmetric information or market power, and then transfer the markups to private income (Bajari Patrick et al. 2014).

In this paper, we attempt to formulate a game-theory model to explore an optimized bidding procedure in public construction projects which can control or reduce corruption, assuming that the tenderers' preference is open. The results show: Just like other non-cooperative auction or reverse-auction Game model with the premise that the only information available to bidder is the tenderers' preference (Hong Wang 2016; Abreu D. 1986), there is a sub-game perfect Nash equilibrium in the multi-attribute bidding game model in public construction projects when tenderers' preference is open without communication and transfer payment; The tenderer's residual utility and the bidder's profit respectively have an U–shape relationship with bidding quality and construction period, which means the bidder's profit is respectively an increasing function of its bidding quality and construction period. Then, after the bidding quality and construction period respectively exceeds a certain point, the bidder's marginal profits of bidding quality and construction period will decrease. Meanwhile, the bigger the tenderer's preference coefficients about committed bidding quality and construction period, the greater the bidder's profit will be. Thus, the tenderer may gain greater surplus if all bidders are more positive in bidding. On the other hand, the greater the coefficients of the bidder's construction quality and construction period, the more competitive are the bidders to win the bidding and be involved in the public construction projects.

Transparency is usually proposed as an effective anti-corruption practices depending upon some understanding and analysis of the practices and politics in developing countries (Dean Neu, Jeff Everett, Abu Shiraz Rahaman 2015). The possible reason is that civil servants and politically connected people can create administrative hurdles and profit from obscure and inconsistent policies and laws (Mathieu Tromme 2016). In order to prevent such corruption, some people propose that the government should be recommended to intervene in the bidding process, but the results are just the opposite (Maria Ostrovnaya, Elena Podkolzina 2015). In this paper, we achieve the conclusion that a buyer of public construction projects who adopts extremely severe regulation can exclude the corruption and attain maximum social welfare. In other words, the buyer of public construction projects who aims to maximize his own profit just should make a simple rule to increase the transparency of bidding process rather than tolerate any degree of the corruption.

To summarize, the main conclusions emerging from our analysis show that if the tenderers' preference is open, which means more transparency in public construction projects to some extent, the bidders are more likely to focus on improving their bidding strategies rather than bribery or other corruption behaviors. Such conclusions can help policymaker to perfect the bidding system of public construction projects and normalize the bidding behaviors of tenderers and bidders. Meanwhile, we suppose the tenderer's preference coefficient will be truly informed of all bidding participants when we are formulating the multi-attribute bidding model about public construction projects. We did not consider the strategies of the tenderer and the bidders of public construction projects while tenderers' preference is hidden, and this is possibly an expansion of our future study. We leave it for future research in endeavor to fully explore this important issue.

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