Review of Theoretical Research and Application of Game Theory in Preventing Together-Conspired or Colluded Bidding Behavior

Yusi Sun[1]

[1]*Engineering Management, Tianjin University, Tianjin, 300000, China*
Corresponding author. Email: shilishuang@cas-harbour.org

ABSTRACT

As a system to prevent corruption, bidding and procurement has become a high-incidence area of corruption in practice. Project bidding is a complex dynamic game process, there are different degrees of game between the tenderer and the bidder, between each bidder, between the supervision department and the bidder. This paper summarizes the literature contents of using game theory in the past 20 years, and points out that electronic bidding may bring new influence to the prevention of enclosing bidding, which has a certain reference value for the follow-up research.

Keywords: Bidding, Game Theory, Together-conspired and Colluded Bidding.

1. INTRODUCTION

In the 1980s, China officially started the bidding process by utilizing foreign bidding methods. With the issuance of relevant laws, such as the Law of the People's Republic of China on Tendering and Bidding, the bidding activities have gradually embarked on the track of rule of law, further standardizing the order. However, bidding procurement, as a system to prevent corruption, has become a high-incidence area of corruption in practice [1-5]. Engineering bid enclosure and cross bid are two classic forms of bidding collusion. Bid encirclement usually refers to the collusion between bidders, while cross-bidding refers to the collusion between the bid inviter and the bidding agency or between the bid inviter and the bidder. Such behavior will not only harm the interests of the country and the relevant collectives, but also undermine the fair and just market environment and the healthy and orderly competition order.

With the continuous improvement of game theory, it has been widely used in the field of bidding. When people use game theory to study bidding and procurement, it can explain some phenomena well and help to design bidding mechanism to a certain extent. The reputation theory, principal-agent relationship theory, incentive theory and so on have been fully utilized in the study of bidding and chain bidding by using game theory. Project bidding is a complex dynamic game process, there are different degrees of game between the tenderer and the bidder, between each bidder, between the supervision department and the bidder. The application of static incomplete information game model can explain many phenomena in bidding relatively perfectly. At the same time, on the one hand, people design more specific rules for the tenderee. Roger B.Myerson [6], Efficient Mechanism of Bilateral Trading, Thomas R.Palfrey, Mechanism Design with Incomplete Information: A Solution to the Implementation and so on. The design of auction rules under incomplete Information is deeply studied. On the other hand, the earliest Research on bidding decision theory can be traced back to 1956. Friedman.L wrote a paper in "Operation Research" and put forward the Friedman Model, which is still one of the most important theoretical models in the bidding field [7]. Later, many experts proposed the Gates Model, Hanssman-Rivett Model, Casey-Shaffer Model, Willenbrock Model, etc. Although the original model was improved, it still could only reflect the simple pursuit of a single criterion by decision makers, with their own defects. These models formed the basis of later studies. The purpose of this paper is to comb through the theoretical research and application of game theory in cross-bidding and surrounding-bidding in the past 20 years, and at the end of this paper, it gives the direction of further research in the future, which has certain significance for the follow-up research.

2. RESEARCH ON COMMON BIDDING METHODS

Vickrey. W [8] (1961) made a further study on the second-price sealed bidding, which was the first time he used the game theory method to solve the auction problem. Since then, scholars have conducted further studies on the role of common tendering and bidding methods in preventing enclosing bids and bunching bids. In 2007, RC Marshall and LM Marx [9] made a comparative analysis and study on the collusive bidding between bidders in the first-price auction and the second-price auction. In this paper, the bidding equilibrium problem of collusion alliance under two typical pre-bidding mechanisms (cooperative bidding mechanism BCM and unified bidding mechanism BSM) is studied.

3. ANALYSIS OF BIDDING RULES AND PROCEDURES

It is an important part to analyze the bidding mode, rules and process by using the game theory. Scholars hope to provide a basis for finding a set of standard and reasonable rules and procedures according to the theoretical analysis, so as to prevent the occurrence of range labeling. Zhu Yabing [10] used the rent-seeking theory in his paper to analyze the political rent-setting and rent-seeking behaviors of government officials in the bidding and tendering of construction projects, and pointed out that such behaviors brought low efficiency to the operation of bidding and tendering mechanism. In 2002, Zhang Ying [11] analyzed the auction theory principle and game theory principle of bidding mechanism in her dissertation. It uses the game theory to analyze the process of rent-setting and rent-seeking. At the same time, the supervised rent-seeking model is considered. The higher the rent-seeking cost is and the more the rent-seeking money is, the smaller the rent-seeking probability is. The higher the supervision cost, the greater the probability of rent-seeking. However, the supervision game model only considers economic factors, which is difficult to be reduced to a constant, not to mention the psychological cost, rent-seeking cost, supervision efficiency and the possibility of illegal behavior of supervisors themselves. In 2003, Li Zhiyong [12] pointed out that the bidding system could be optimized based on several assumptions. He introduced the principal-agent theory to analyze the choice and moral problems between principals and agents.

The game model is also crucial to the research of researchers. Deng Peilin and Zhang Ruiming [13] established a game model of collective interest alliance by using game theory in Game Analysis of Tendering and Bidding Corruption, and analyzed the interdependence among alliance members in the game

process in view of the corruption problem of "profit sharing alliance" in tendering and bidding projects. Xia Jiechang and Yang Xin [14] studied rent-seeking behavior and its internal mechanism in government competitive bidding through the expected utility function of suppliers and purchasers. Wang Mingfeng, Zhang Yunbo, Hu Wei et al. [15], based on the static game model, analyzed the internal mechanism of cross-bidding behavior between bidders by using game theory and the "Prisoner's Dilemma" game model. The practical feasibility of this model is proved by an example, and a series of measures are put forward, including standardizing and punishing the cross-bidding behavior from the aspect of laws and regulations. Vianney(2007)[16] studied the optimal auction mechanism under the condition of bidder collusion and described the auction process as a Stackelberg (duopoly market) game model. First, the bidder proposed an optimization mechanism, and then a "virtual third party" proposed a contract for private collusion between bidders. Then all bidders participate in the contract collusion at the same time, and finally all bidders participate in the optimization mechanism of the bid-issuing side at the same time. Under the optimal auction mechanism, information asymmetry between the bidder does not limit its complicity in ability, when "virtual third party" the implementation of monetary transfers between bidders, or at the same time, the implementation of monetary transfers and auction subject matter redistribution, collusion will not affect the efficiency of the optimal auction tenderee.

In addition, in the bidding process, the relationship and behaviors between different stakeholders can also be analyzed through game theory. Cui Jianzhu [17] pointed out that bidding is essentially a game process between different stakeholders. This paper analyzes the phenomenon of bidding collusion in the bidding process, mainly discusses the bidding collusion behavior from the theoretical level by using Nash equilibrium game, and analyzes the profit formula of bidding collusion, so as to get the management countermeasures of bidding collusion. Shiran (2013) [18] studied the problem of bribery collusion among bidders in the first-price auction (that is, one bidder exchanged for another bidder to abandon the bid through bribery), simulated it as a multi-stage signal abandonment, and analyzed the existence conditions of its abandonment equilibrium. When the normalized value type of the bidder obeies the continuous uniform hog-distribution in the unit interval, if the minimum value type of the bidder is strictly positive (far enough away from 0), there may be a non-trivial equilibrium involving bribery, and it must be a mixed strategy equilibrium solution. Liu Hao and He Shoukui [19] applied the evolutionary game theory to analyze the expected benefits of bidders, bidders and governments under different decisions, aiming at the bid enclosure problem in bidding

activities, and built an asymmetric evolutionary game model of the three parties under the incomplete rational condition. At the same time, the system dynamics model is used to simulate the evolution process of the three parties in the game, and the main factors affecting the behavior of the players in the game are analyzed from the perspective of government regulation cost driving. In 2020, Zhu Wenxi, Guo Yabin, Chen Yun, Li Jingjing et al. [20] studied the calculation model of bidding interval between bidders and bidders' collusion. In order to reveal the variation rule of quotation interval in the process of "intent-negotiation-formation" between tenderee and bidder, and to explore effective countermeasures to accurately control collusion behavior, the expected utility function of the collusion intention between bidder and tenderee was constructed, and the quotation intention interval and negotiation interval of the collusion were calculated. The results show that increasing δ and β can reduce the distance of collusion bidding interval, and the influence of control R on the distance of collusion bidding interval is different in the three cases.

4. THE DEVELOPMENT OF GAME THEORY IN BIDDING

As a comprehensive application of game theory and social choice theory, mechanism design theory is a typical Bayesian game (static game with incomplete information). For mechanism design, the tenderee needs to solve three aspects of the problem: Firstly the design of incentive mechanism. Rational bidders should be interested in accepting the mechanism designed by the tenderee so as to participate in the game, which requires the tenderee to design a reasonable incentive mechanism so that the expected utility obtained by the bidder in the participation mechanism is greater than or equal to the maximum expected utility when the bidder does not participate. Secondly, the design of supervision mechanism. Where conditions permit, we should try our best to eliminate the information asymmetry between the tenderer and the bidder, so that each party can monitor the type and behavior of the other party. The design of constraint mechanism. In the case that the tenderee does not know or know little about the type of the bidder, the bidder is constrained to actively choose the behavior desired by the tenderer. This part will further discuss the development and changes of game theory in bidding

In 2003, Fu Xiaoling [21] analyzed the game relationship in tendering and bidding, and held that it was an incomplete information game, and proposed an incentive mechanism to maximize the tenderer's utility under the condition of considering participation constraints and incentive compatibility constraints. S. Peringho [22] (2004) constructed an analysis model based on game theory, namely power decision model (CDM), to study opportunity bidding and construction claim based on the understanding of the dynamic relationship between construction claim and opportunity bidding. The model explains how people behave in the context of potential or existing claims, how different complaint situations differ from opportunistic bidding behavior, and what would encourage or discourage opportunistic bidding. The results show that, consistent with most claim cases in the industry, the balanced solution for constructive claims is negotiated settlement.

In 2007, Ren Hong and Zhu Lianbo [23] applied signal game theory to establish a dynamic game model with incomplete information in view of the bidding and chain bidding behavior in the construction market. Through the solution of the model, it is concluded that the main factors affecting the collusion are the penalty fee of the tenderer and the cost of checking the cross-bid. In 2007, based on the game theory, Zhang Hongyan designed the incentive, constraint and supervision mechanism for the tenderer from the perspective of the bidder, and thus carried out the research on the centralized bidding and procurement mechanism. Part of the research results have been applied in the bidding and procurement activities of State Grid Corporation of China [24]. Liu Jianbing and Ren Hong [25] analyzed the basic problems of the principal-agent relationship and designed the incentive and constraint mechanism for the bidding of engineering projects by identifying the principal-agent relationship in the bidding of engineering projects. Through the mechanism design and analysis, it is concluded that the bidding and tendering of construction project not only needs to realize the incentive and constraint through mechanism design, but also needs to pay attention to the incentive and constraint function of non-mechanism factors such as ideology, system arrangement and system arrangement, soft constraint of culture and morality.

Zhang Dingzu and Zhao Hua [26] used contract theory, principal-agent theory and auction theory to analyze the internal mechanism (information asymmetry, incentive imbalance, disorderly competition, power rent-seeking, etc.) and external environment (lack of integrity, defects of regulatory system, imperfect property rights system, etc.) of construction project bidding collusion. It is suggested that the internal mechanism and external environment should be improved to prevent the collusion in bidding of construction projects. Based on classic auction (bidding) model and game theory, Wang Yuanyuan et al. (2009) studied two game models that considered bribing bidders having the right of refusal and allowing affiliated bidding under the evaluated lowest bid evaluation rules, and bidding (agent) parties creating lease under the comprehensive bid evaluation rules [27].

Yeon-koo and Jinwoo[28](2009) established a suboptimal auction model by applying the mechanism design theory, and proved that the auction result is suboptimal when the auction rules make at least one bidder unwilling to participate in colluded bidding, or there is more than one bidding alliance, or when the auction subject is not allocated to any bidder with non-zero probability in the equilibrium result. Moreover, no matter whether the bidders may collude in the bidding or in the decision of participation, the collusion ability is effectively weakened by the information asymmetry between bidders.

Zhou Jin 'e [29] (2010) analyzed the forms of horizontal collusion in construction project bidding and its causes, confirmed that horizontal collusion is different from moral hazard and adverse selection, but a new agency problem, and summarized the relevant measures to prevent horizontal collusion in practice. It can be considered from two aspects: improving internal governance (qualification examination, bid evaluation method, performance guarantee, bidding system, incentive of bid evaluation experts of agency, etc.) and external governance (reputation mechanism of bidders, regulatory punishment, etc.). But the effectiveness of this mechanism needs to be verified, and there is a lack of case analysis, and there is no good combination of vertical and horizontal collusion for in-depth research.

Fan Ruguo and Li Dan [30], aiming at the phenomenon of bidding enclosure in the construction market, used the evolutionary game method to construct the evolutionary model of bidding strategy in the construction market. By solving the model, the paper analyzes the decisive factors affecting strategy equilibrium, obtained in the lowest bid, a bidder's benefit and surround mark extra profits, as well as in the bid to correctly determine the utility cost of bidders, surrounded by determining bidding cost reasonably, can better prevent the occurrence of this phenomenon. In 2017, Chen Lu [31] applied the cooperative game theory and non-cooperative theory of enterprise management to analyze the four-layer game relationship, the ideal game relationship and the desired result in the bidding activities of engineering materials, and put forward solutions to realize the ideal game relationship of the tenderer, and verified the solutions with examples.Through multi-angle, multi-aspect theoretical analysis, with the case to prove the prevention and control effect. For the part of theoretical proof, most of the domestic stay in the level of repeated proof. At the same time, there are also a lot of literature combined with the local reality, the cause of the surroundingbidding and cluster of the form of expression and countermeasure are studied, and put forward a lot of constructive suggestions.

5. CONCLUSION

The phenomenon of surrounding-bidding and cross-bidding has always attracted attention. There are many domestic and foreign researches on the forms and characteristics of surrounding-bidding and cross-bidding from the perspective of game theory. Based on the analysis of the causes of surrounding-bidding and cross-bidding, many governance strategies and bidding mechanisms have been proposed and designed based on the analysis of actual cases in various places. Some of these studies have been put into use and achieved some results. The application of game theory has been relatively mature. There have also been a lot of demonstration, design and empirical analysis on the multiple incentive model of contract bidding, the negotiation and decision of both parties, fuzzy comprehensive evaluation and artificial neural network.

However, with the development of electronic bidding and the application of BIM technology, the background of the new era presents new challenges for the research. After BIM technology is applied to engineering electronic bidding, BIM through the establishment of 3 d model through the bidding of the whole process, to realize information sharing, effectively avoid the traditional bidding each link in the lack of connectivity, the defects of incomplete information sharing, surround the string of the underlying difficulty getting high, more convenient to review the bid assessment committee to carry out the project. On the other hand, electronization only reduces the relevant influence from the technical level, and the change of the current system mechanism still needs further study.

REFERENCES

[1] G. He. Work Report on the Seventh Plenary Session of the Seventeenth Central Commission for Discipline and Supervision of the Communist Party of China. 2012, 1.

[2] Y. Wang. Institutional Innovation for Containing Tendering and Bidding Corruption. Economic Information Daily. 2011-10-13.

[3] G. Sun. Bidding is still the key point of preventing corruption in construction field. Procuratorial Daily, 2009-09-01.

[4] Y. Jiang. (Xinhua Review) The Flooding of Bidding Corruption Roots from the ineffective crackdown. 2009-01-07.

[5] B. Zhou. The industry spread "no bid, no string" anti-corruption tool has also been corroded bid encircling string bid with the unwritten rules of bidding. Legal Daily. 2009-11-19.

[6] D. Emblen. Competitive bidding fore orporate seeurities.Ph.D. Dissertation. Columbia University, New York. 1944

[7] L. Friedman. Competitive bidding strategy. Ph.D. Dissertation, Case Institute of Technology. Cleveland, Ohio. 1957

[8] W. Vickrey. Counter speculation,auctions,and competitive sealed tenders. The Journal of finance. 1961, 16(1):8-37.

[9] R.C. Marshall, L.M. Marx. Bidder collusion. Journal of Economic Theory. 2007, 133(1):374-402.

[10] Y. Zhu. Model analysis of government behavior and rent-seeking in construction project bidding. Journal of Lixin Accounting College. 2001(01):32-36.

[11] Y. Zhang. Theoretical and Practical Research on Tendering and Bidding in China. Zhejiang University. 2002.

[12] Z. Li. Research on Anti-corruption Mechanism in China's Engineering Bidding. Southwest Jiaotong University. 2003.

[13] P. Deng, R. Zhang. Game Analysis of Bidding Corruption. Journal of Southwest Jiaotong University. 2003(06):691-694.

[14] J. Xia, X. Yang. Analysis of rent-seeking behavior in government competitive bidding procurement. Finance and Trade Economics. 2003(4):52-55.

[15] M. Wang, Y. Zhang, W. Hu. Journal of Hefei University of Technology (Natural Science Edition). 2008(09):1503-1505.

[16] V. Dequiedt. Efficient collusion in optimal auctions. Journal of Economic Theory. 2007, 133(1):374-402.

[17] J. Cui. The application of game theory in the management of surround-bidding and series bidding. Economic Research Guide, 2012(28):210-212.

[18] S. Rachmilevitch. Bribing in first-place auctions. Games and Economic Behavior. 2013,77(1):214-228.

[19] H. Liu, S. He. Game analysis on the evolution of bidding enclosure behavior of construction enterprises driven by regulatory cost. People's Changjiang. 2020, 51(08):177-185.

[20] W. Zhu, Y. Guo, Y. Chen, J. Li. Journal of Railway Science and Engineering, 2020, 17(11):2969-2976.

[21] X. Fu. Analysis on the incentive mechanism in engineering bidding. Engineering Construction and Design. 2003(12):26-28.

[22] S. Ping, L. Ho, Y. Liu. Analytical Model for Analyzing Construction Claims and Opportunistic Bidding.Journal of Construction Engineering and Management. 2004, 130(1):94-104.

[23] H. Ren, L. Zhu. Signal game analysis of series bid behavior in engineering bidding. China Civil Engineering Journal. 2007(07):99-103+110.

[24] H. Zhang. Research on centralized bidding procurement mechanism based on game theory. Beijing Jiaotong University. 2007.

[25] J. Liu, H. Ren. China Collective Economy. 2008(19):80-81.

[26] D. Zhang, H. Zhao. Construction Economics. 2008(06):100-103.

[27] Y. Wang, D. Zhao. Journal of Engineering Management. 2012, 26(01):33-38.

[28] Y. Che, J. Kim. Optimal collusion-proof auctions. Journal Of Economic Theory. 2009, 144(2):565-603.

[29] J. Zhou. Analysis on the phenomenon of lateral collusion and governance mechanism in construction project bidding. Tianjin University of Technology. 2010.

[30] R. Fan, D. Li. Value Engineering. 2011, 30(01):64-66.

[31] L. Chen. Discussion on the relationship between game theory and material bidding work. Finance and Economics (Academic Edition). 2016(30):40+56.