Development of Effective Mechanism Order Allocation in the State Procurement

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Abstract. The problem of the efficient order allocation in the state procurement in conditions of incomplete information concerning the parameters of agents’ utility functions is considered. The change mechanism order allocation is suggested. New mechanism is more effective because it includes penalty system. Through business game the results are modelled and compared in conditions of incomplete information concerning the agents’ utility functions. We experimentally prove the inexpediency of information distortion of the agents’ effectiveness when using a non-manipulative distribution mechanism in a multi-step game.

1. Introduction

The orders distribution and the supplier selection through the public procurement system are mandatory for all state-owned companies. It is also a necessary process for commercial companies that claim to be the executor of such an order. There are some different tools for the order distribution and the supplier choice [1, 2]. We describe the auction. There is used type of priority mechanism. The ones is manipulated mechanism. This mechanism has some problems. There are many proposals on how to improve the government orders allocation quality in terms of law. At the same time, mathematical approaches to improvement have been successfully applied in other fields. Algorithm or distribution mechanism should be changed [3, 4, 5]. We suggest more effective mechanism. New mechanism should be non-manipulative.

2. Basic concepts and notation

The public procurement process is regulated by Federal Law No. 44-FL "On the contract system in the procurement of goods, works, services to ensure state and municipal needs" [6]. This law determines that the supplier choice is made in accordance with the auction mechanism [7]. Supplier who will offer the minimum price for the performance of the contract gets the order. The first problem is the understatement of prices by the winner. These prices are often lower then costs. This situation leads to a problem in the performance of the contract, a decrease in quality and, in frequent cases, additional payment when the supplier is unable to fulfill the obligations assumed [8]. Another problem is the inability to fulfill the contract independently and transfer it to subcontractors. This increases the costs of the contract.

The procurement participants qualifications are used as criteria for evaluating procurement participants [9]. These ones are the financial resources availability, ownership or other legal basis for equipment and other material resources, work experience related to the subject of the contract, and business reputation, specialists and other employees of a certain skill level.

Qualitative characteristics in the existing mechanism are used at the stage of selection of participants in the auction. The scientific novelty of the work is that we propose to use this indicator to
calculate the rating price. This price determines the winner of the auction. We use penalty system also. Mechanisms using penalty systems [5] are non-manipulative, which increases the efficiency of resource allocation in the system.

3. The study purpose
It is necessary to modify the auction mechanism for order distribution in the public procurement system. We suggest theory that in the case of a repetitive public procurement process, suppliers will acquire some knowledge about the environment and can adjust the prices in such a way as to achieve the desired result. We need check this one.

Tasks we have:
- a modified auction mechanism should be developed;
- computational experiment in complete information conditions about the players utility functions should be made;
- computational experiment in incomplete information conditions about the utility functions of players should be made;
- a comparative analysis of the results obtained should be made.

4. The modified mechanism description
Competitions (open tender, limited tender, two-stage tender, closed competition, closed competition with limited participation, closed two-stage tender) and auctions (electronic auction (hereinafter also electronic auction), closed auction) are competitive methods for determining suppliers (contractors, executors). The competition is the way to determine the supplier (contractor, performer). The winner is the bidder who offered the best conditions for the performance of the contract. Auction is the way to determine the supplier (contractor, performer). The winner is the bidder who offered the lowest price of the contract.

Procurement participants must meet certain requirements [6].

Current mechanism consists of 5 stages.
1. Selection according to quality criteria.
2. Declaring the maximum an order price ($p_{max}$)
   \[ p_{max} = \frac{p_1 + p_2 + p_3}{3}. \]
3. Receiving applications from auction participants.
4. The rating formation.
5. Selecting $p_{min}$ from the rating.

But, statistics says that some of auctions are not effective. Some participants do not fulfill contracts, other prices of contracts are increased to be fulfill. Participants could to decrease prices very much to win. So, we suggest a modified mechanism. First of all we need to add a penalty system. If price somebody participant is very high, than should be charged a penalty. If price somebody participant is very low, than should be charged a penalty. We also include qualification parameter as price coefficient.

In accordance with the requirements of the Federal Law participants are selected to meet certain parameters on the first stage.

Next, the maximum auction price is announced. This price is calculated as the average value of prices offered by the largest participants in the market. Usually, the survey of the three largest suppliers prices is carried. This approach ensures the relative adequacy of the maximum price. This means that price will not be either too high or too low. It also theoretically guarantees that the price of the order will be attractive to the participants of the auction.

The auction takes place on-line. The auction is multi-step. Each participant sees the rating prices of other participants. And they can offer other price at the next stage.

5. The effective mechanism order allocation
Modified mechanism needs more stage for calculation.
First of all, we support the idea of selecting auction participants to parameters to exclude deliberately "weak" participants. Weak participants haven’t enough financial, material resources and experiences to be good executors.

Next, the maximum auction price is announced. This solves the problem of overstating the price of the contract. Just like in the initial auction, this price is calculated as the average price offered by the largest players in the market. The survey of the three largest supplier prices was carried.

The problem of offering a too low price, which does not ensure the cost of the contract, is suggested to be solved by determining the average level of costs. The average level of costs is determined by the Economic Ministry statistics. If the price is above the average level of costs by more than a certain percentage, then it is necessary to adjust the price. Corrective coefficient should make rating price higher. It is penalty for incorrect price. If the price is much less than the average level of costs, this may indicate dumping. Such a situation is punishable by the inclusion of an upward coefficient.

6. Selection according to quality criteria
We use the financial resources, equipment and material resources amounts, work experience, specialists, business reputation as quality criteria.
1. Declaring the maximum an order price ($p_{\text{max}}$)
   \[ p_{\text{max}} = \frac{p_1 + p_2 + p_3}{3}, \]
   where $p_1, p_2, p_3$ are main suppliers prices should be used to calculate the maximum an order price.
2. Determining the costs average level ($\bar{c}$) for the order execution.
   Statistic information from government should be used to calculate costs average level.
3. Collection of applications ($p_i, k_i$), where $k_i$ is player's quality factor, determined by criteria.
   This information should be used as correction factor.
4. A penalty ($s_{ti}$) for exceeding the price by more than $a$ % of the average cost level accrual.
   \[ s_{ti} = a(\bar{c} - p_{ti}) \]
   where $p_{ti}$ is price $i$-st of supplier at time $t$, $\bar{c}$ is average cost.
   If $p_{ti}$ more than $\bar{c}$ it means that supplier uses incorrect price to win. It should be right correct his/her price with coefficient $a$.
5. A penalty ($s_{mi}$) for deviation from the maximum price by more than $b$ % accrual.
   \[ s_{mi} = b(p_{\text{max}} - p_{ti}) \]
   where $p_{ti}$ is price $i$-st of supplier at time $t$, $p_{\text{max}}$ is maximum price.
6. Calculation of the rating prices taking into account the quality factor and penalties.
   \[ p'_{ti} = a_i \cdot b_i \cdot k_i \cdot p_{ti} \]
   $a_i$ and $b_i$ are coefficients that correct $i$-st supplier price because initial price $i$-st supplier wasn’t correct, $k_i$ is coefficient that decrease rating price because supplier has good parameters.
7. The rating formation.
8. The supplier who has lowest rating price should be at the top of the list. On the contrary the supplier who has highest rating price should be at the end of the list.
9. Selecting $p'_{\text{min}}$ from the list.

7. Computer experiments
Computer experiments were used in two variants. First game variant expected to establish the price within the competition for the selection of the supplier in the system of state purchases in the conditions of incomplete knowledge of the players’ utility functions of competitors. Second game variant expected to establish the price in the competition for the selection of the supplier in the system of state purchases in the conditions of complete knowledge of the players’ utility functions of competitors.

Table 1 shows the participants’ parameters.
Table 1. Participants’ parameters.

| Parameter/Participant | $P_1$ | $P_2$ | $P_3$ |
|-----------------------|-------|-------|-------|
| $C_i$                 | 100   | 120   | 110   |
| $K_i$                 | 0.9   | 1.2   | 1.5   |
| $P_{max}$             | 214   |       |       |
| $C_{cp}$              | 123   |       |       |
| $\alpha$              | 0.2   |       |       |
| $b$                   | 0.1   |       |       |
| $a$                   | 1.4   |       |       |
| $b$                   | 1.5   |       |       |

where $C_i$ is $i$-st participant costs, $K_i$ is $i$-st participant quality coefficient, $P_{max}$ is maximum price of auction, $C_{cp}$ is average costs, $\alpha$ is allowable difference between $i$-st participant price and average costs, $b$ is allowable difference between maximum price and $i$-st participant price, $a$ is penalty amount to very high price, $b$ is penalty amount to very low price.

The better the qualitative characteristics of the enterprise, the less $K$. Obviously, the first enterprise looks the most promising in terms of parameters.

Table 2 shows the changes of initial and rating prices on different game steps within the competition for the selection of the supplier in the system of state purchases in the conditions of complete knowledge of the players’ utility functions of competitors.

Situation with incomplete information means that participants don’t know about quality coefficients their competitors. They have limited information to make decision. They know own parameters and competitors rating prices.

Situation with complete information means that participants know about quality coefficients their competitors. They have more information to make decision. They know own parameters and competitors rating prices.

Table 2. The game results to establish the price within the competition for the selection of the supplier in the system of state purchases in the conditions of incomplete knowledge of the players’ utility functions of competitors.

| Participant/Step | 1  | 2  | 3  |
|------------------|----|----|----|
| P1               | 214| 190| 180|
| P2               | 194| 150| 145|
| P3               | 193| 190| 160|
| P1’              | 192.6| 171| 162|
| P2’              | 213.4| 375| 362.5|
| P3’              | 193| 190| 384|

where $P_i$ is initial price of $i$-st participant, $P_i'$ is rating price of $i$-st participant, bold figures are best prices.

Price dynamics is explained corrective coefficients and multistep games. So, if supplier saw that his/her rating price worth than other prices he/she could decrease initial price and vice versa. We can see that different mechanism chooses different winner.

Rating price calculates as initial price adjusted for penalties and quality coefficient. Penalties increase rating price. Quality coefficient can both increase and decrease rating price.

Price dynamics is explained corrective coefficients and multistep games. So, if supplier saw that his/her rating price worth than other prices he/she could decrease initial price and vice versa. We can see that different mechanism chooses different winner.

Comparing situations with complete and incomplete information we can see that incomplete information better for center than other. When participants know about his/her preferences over competitors he/she appoint a higher price.
Table 3. The game results to establish the price within the competition for the selection of the supplier in the system of state purchases in the conditions of complete knowledge of the players’ utility functions of competitors.

| Participant/Step | 1  | 2  | 3  |
|-----------------|----|----|----|
| P1              | 214| 214| 214|
| P2              | 200| 150| 145|
| P3              | 200| 110|  90|
| P1’             | 192.6| 192.6| 192.6|
| P2’             | 220| 375| 362.5|
| P3’             | 200| 264| 216|

where \( P_i \) is initial price of \( i \)-st participant, \( P_i’ \) is rating price of \( i \)-st participant, bold figures are best prices.

8. Results

We suggest modified mechanism order allocation in the state procurement. We change stages quantity and include some coefficient to calculate rating prices. This way allows to take into account if initial price of \( i \)-st supplier was correct or incorrect. Due to penalties to incorrect initial price choice should be right.

A computer experiment was carried out. More than 50 games were played in different target audiences. The conducted experiments showed that the proposed algorithm provides higher efficiency of placing an order in the public procurement system. The efficiency is determined by the reduction in the number of orders not fulfilled in time and the reduction in the amount of additional payments for distributed orders.

9. References

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