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ECONOMIC EFFICIENCY AS ONE OF THE MAIN OBJECTIVES OF AUCTION DESIGN

Summary: Auctions are commonly used in case of narrow markets as the useful mechanisms which promote competition and help increase the revenues or lower the costs (in case of procurement). But many economists argue that an even more important objective of the auction design should be efficiency, which roughly means that the object is allocated to the participant, who values it the most.

The paper analyzes the concept of economic efficiency and presents arguments why efficiency should be treated as an important objective of the auction design. It also shows that efficiency can be to high extent controlled through a careful design of the auction rules. Laboratory experiments serve as a useful tool which helps tailor those rules to meet the auctioneer's goals.

Keywords: economic efficiency, Pareto efficiency, auctions, experiments.

1. Introduction

Auctions are the market institutions which determine the allocation and prices on the basis of bids received from the market participants. There exist many auction mechanisms, differing by the explicitly stated set of rules. An important benefit of auction is that its design can be tailored, depending on the auctioneer's needs and the market situation. Some auction mechanisms turn out to work better when the competition is low, or when there are strong asymmetries between the bidders, some are better at preventing collusion, and so on.

The application of the particular auction design depends on the auctioneer's goal. When the auction[1] is started by the seller, the first obvious objective is to sell the object at the highest possible price, so as to maximize the seller's revenues. Auction

[1] The term "auction" will be used in this paper in two meanings. First, as in the first paragraph, the auction is defined as the market institution, i.e. set of rules. Second, as in this meaning, it will be understood as a particular market. For example we might be talking about the "English auction" (by which we understand a specific set of rules) or about the "Netherland's UMTS auction" by which we understand an application of the auction mechanism in a specific market. Those two meanings are interchangeably used in economic literature and hopefully it will be not confusing.

mechanisms are especially useful in case of the narrow markets, when there are not many economic agents interested in buying the object. The good property of the auction is that it introduces competition in such markets, enabling the seller to reach the highest possible price. By analogy when the auction is started by the buyer, the most obvious goal is to find the cheapest supplier or contractor, so as to minimize the costs (such auctions are called the procurement auctions).

But many economists actually argue that revenue/cost objective should not be considered the most important one by auction designers. To quote Vernon Smith: "As economists our task is to emphasize that efficiency, not revenue, is the key criteria in economic systems design. For government sales of rights and assets, efficiency is the route to maximizing the creation of income and wealth in the economy, and that gives you more tax revenue tomorrow. To the extent that the FCC auctions have maximized revenue and contributed to the winner's curse, they have contributed to bankruptcies, spoiled the market for subsequent auctions, and reduced the generation of new wealth. For private auctions, public policy should lend support to programs for achieving efficient allocations"[2]. What should we understand by the "efficiency"? The formal definition of this criterion and its discussion is given in the next part, but to have a rough idea about it we can quote U.S. Vice President Al Gore, who, during a debate on efficiency of FCC auction in 1994, called it "putting licenses into the hands of those who value them the most"[3]. In the next parts the author analyzes why this should be considered an important objective of the auction design, and how to ensure the auction's efficiency.

2. Efficiency

The intuitive notion of efficiency, as of selling the objects to the bidders who value them the most, turns out to correspond with the standard economic concept known as Pareto efficiency. The allocation is called Pareto efficient if there does not exist a Pareto improvement, i.e. an allocation which would make at least one participant strictly better off, without worsening the situation of any other participant.

Proposition. The auction is Pareto efficient if and only if it allocates the object to the bidder for whom it has the highest value. Accordingly, the procurement auction is efficient if and only if it allocates the contract to the bidder with the lowest costs.

Proof. We will prove the Proposition for the case of standard auction; the proof for the procurement auctions is analogical. Let us assume that the first bidder has the highest valuation of the object, which equals v_1. The value of the object for the seller

[2] *Combinatorial Auctions*, ed. P. Cramton, Y. Shoham, R. Steinberg, The MIT Press, Cambridge MA, 2006, p. xiv.

[3] P. Milgrom, *Putting Auction Theory to Work*, Cambridge University Press, Cambridge 2004, p. 4.

is v_0. Let us say that the auction was not won by the first bidder, but by the second one, with valuation v_2, who offered the price p. The following inequalities must hold:

$$v_0 \leq p \leq v_2 < v_1 .$$

The first one results from the fact that the seller must have an incentive to sell the object, and the second one from the fact that a rational bidder will not offer a price higher than his valuation[4]. The payoffs vector is given by:

$$\Pi - (p - v_0, 0, v_2 - p, 0, 0, ..., 0),$$

with the first element showing the payoff of the seller, and the rest showing the payoffs of the subsequent bidders.

It is easy to notice that this allocation is Pareto inefficient, as there exists a Pareto improvement. Let us say that the object was sold to the first bidder for the price p, and that additionally he made a money transfer to the second bidder, equaling $v_2 - p + \varepsilon$, with $0 < \varepsilon < v_1 - v_2$. In this situation the payoffs vector is given by:

$$\Pi' = (p - v_0, v_1 - v_2 - \varepsilon, v_2 - p + \varepsilon, 0, 0, ..., 0).$$

The seller's payoff is unchanged, but the first and second bidders' payoffs are higher. As ε was assumed to be smaller than $v_1 - v_2$, the first bidder's payoff is now strictly positive. And the second bidder's payoff has also increased, as ε is positive. This proves that for the allocation to be Pareto efficient, the object must be allocated to the bidder with the highest valuation (otherwise there exists a Pareto improvement).

To prove that every allocation, in case of which the object goes to the bidder with the highest valuation, is Pareto efficient, it suffices to observe that in this situation the total surplus of all bidders is maximal (equaling $v_1 - v_2$) and so no Pareto improvement can exist.

Q.E.D.

The money transfer that the first bidder makes to the second bidder to reach the Pareto optimality looks strange at the first moment, but there are at least two ways to interpret it. First, one can think of it as the money paid by the first bidder to the second one, so that he does not participate in the auction. Second, and more important, it can be interpreted as resale, which benefits both sides. A "resale" interpretation is important because it is used by some economists as an argument against the importance of the efficiency criterion. Those economists (typically attributed to the Chicago school) claim that efficiency is not important because it can always be reached in the market ex-post.

There are at least two arguments against this point of view. First one is that in the presence of the transaction costs it might not be profitable for the two participants to

[4] Actually, none of these two inequalities is needed for the Proof. They are only set to guarantee that the participants' payoffs are nonnegative.

trade the object ex-post. The other one has to do with the asymmetry of information. With asymmetric bidders, the sealed-bid auction with a resale option afterwards does not have to end up with the efficient outcome. The reasons are strategic: if the bidders are aware of the resale possibility, they incorporate this fact in their bidding strategies, which in a situation of the asymmetry of information (the bidders do not know the true values of the object for the other bidders) might disable them from reaching an efficient allocation through the resale[5].

Efficient allocation in case of an auction is the one which maximizes the total surplus. Le us observe that the situation when the object is sold to the bidder, who did not value it the most, is not the only example of inefficiency. The auction is also inefficient when, even though there existed economic agents who valued the object higher than the seller, none of them actually offers a price high enough and no winner is determined. This can happen in a situation when the strongest participants, fearing the competition and high entry costs, do not decide to take part in the auction, or when nobody offers a price higher than the hidden reserve price set by the auctioneer[6].

V. Smith also calls an auction inefficient, when it ends up with a winner's curse, i.e. with a situation when the winner pays a price higher than the true value of the object and ends up with losses. In case of procurement auctions the winner's curse takes place when the winning contractor offers a price lower than the costs. These situations can happen when the participants are not sure of the true value of the object, which will be revealed long after the bidding process is completed. Such situations are common. For example when the mobile companies bid for the UMTS technology in 2000-2001 they had no idea how much the 4G market was really worth, as the UMTS technology had not yet been applied in any country. Analogically, in procurement auctions quite often it is difficult to assess precisely the costs of providing a service (e.g. building a tunnel) which can increase dramatically in the future. Let us observe though that this understanding of efficiency is different than just selling the objects to those who value them the most. If the strongest bidder wins the auction, but overpays, than the solution is Pareto efficient (the total surplus is maximal). Smith's argument then goes one step further.

3. Why efficiency matters

But why actually should efficiency be considered so important? Why should we be "putting licenses into the hands of those who value them the most"? The arguments that efficiency is the main economic criterion imply that we should try to design an

[5] For the formal analyses see: V. Krishna, *Auction Theory*, Academic Press, San Diego 2002, p. 54-58.

[6] The last situation can be actually modeled as the previous one. An auctioneer can be looked upon as a bidder in an auction, who makes a bid, equaling the reserve price. If nobody offers a higher price, he is the "winner" (i.e. he keeps the object) even though he did not value it the most.

auction in such a way, that it reaches the efficient allocation even if it is at a cost of lower revenues (or higher costs in case of procurement).

Let us first analyze the public auctions, where the importance of the efficiency is more straightforward. The general argument in this case is that the government's goal (when it acts as an auctioneer) is not to be one of the active economic players, whose goal in the game is to maximize its profits. The government should not try to outsmart the other economic agents; quite the contrary, it should try to create incentives to promote competitiveness, and to reward the most efficient companies. That would make the whole economy work better, which in V. Smith's words "gives you more tax revenue tomorrow".

But it is less obvious, why the economic efficiency should be an important criterion in case of the private auctions. Imagine, you are selling a painting in an auction. Should you really care if it ends up in the hands of a person, who values it the most, or would you just want to sell it for the highest possible price? In this situation the revenue criterion is definitely the most important one. But the importance of the efficiency is more apparent in case of the procurement auction, especially when the quality is not fully contractible, because the auctioneer is unable to control all the elements of the contract. In this situation the efficiency means that the auction is won by the lowest costs contractor, which increases the chances that it would be fulfilled on time, and without serious problems. Let us now say that in a first-price sealed-bid auction[7] the winner is a high cost company, which offered a very low price, being desperate to win the contract. This situation can then result in delays, or problems with the quality, as the contractor would have to cut costs wherever it is possible, to make profits at the price he bid. He would probably try to renegotiate the contract later, claiming that some new, and unexpected events took place, and so on. Is it then not better to pay a bit more, and have an efficient contractor?

Even if there exists no uncertainty concerning the quality (because the procurement is for the supply of some standardized products) it might be beneficial for the auctioneer to promote the efficient outcomes. In the short run it is of course in the buyer's interest to care only about the lowest possible price. But this is not that obvious in the long run. Imagine that the auction design guaranteed that the lowest costs bidder would always win the contract. In this situation there are obvious benefits of being the contractor with the lowest costs. To lower the costs the firms have to take some costly actions (look for cheaper materials, invest in R&D, and so on). When deciding whether to take such actions they are comparing the marginal revenues and the marginal costs, and the optimal level of effort is at the point where the two equal. If the auction is inefficient then the marginal revenues are smaller, as reduction of the costs does not increase the probability of winning as much as it

[7] All participants make sealed bids. The winner is the contractor who offered the lowest price, and he is paid the price, he asked for.

should[8]. But if the marginal revenues are smaller, then the optimal level of the effort is smaller as well; as the companies have lower incentives for the costs reductions. Thus the long run consequence of inefficiency is a higher level of firms' costs and therefore the higher level of prices in the market.

In the next part the author analyzes if there really exists a tradeoff between the revenue/costs objective and efficiency.

4. Efficiency versus revenue maximization

In the previous parts the author shows why efficiency is an important objective in the auction design. But does there really exist a tradeoff between the revenue maximization and efficiency? Well, to some extent not, as both objectives are partly correlated. Actually, it would be impossible to design an auction which guarantees efficiency and does not lead (at least imperfectly) to the maximization of the seller's revenues. In an efficient auction the object is allocated to the bidder with the highest valuation, i.e. to the one who is willing to pay the most. But what is the other way of identifying such a bidder, if not by the price he bids and is able to pay? Imagine that in the auction the participants were only asked to state their maximum willingness to pay (the maximum price that they would be willing to pay). The one who stated the highest price would win the auction, but he would only have to pay the reserve price. Such a system would not work, because the participants would lack incentives to truthfully report their maximum willingness to pay. Even a bidder with a very low valuation could offer billions, knowing that he would only have to pay the reserve price. Only in the situations where bids matter, i.e. the bidders pay the prices they offer, the efficiency can be established. And so an efficient auction will be accompanied by high revenues.

Nevertheless in some situations the auctioneer does have to decide which of the two objectives is more important to him. Compare the two most popular auction mechanisms: English auction and first-price sealed-bid auction. The English auction is always efficient. This results from the fact that in the English auction, which involves an open, dynamic bidding, the highest-value bidder can always outbid the others and eventually he will. Analogically in the procurement auction the lowest-costs contractor is always able to offer a lower price than his competitors and so will win the auction. The efficiency is not guaranteed though in case of the first-price sealed-bid auction. The bidders make sealed bids, without knowing the offers of the other bidders, and have no possibility to change their prices, once the bids of others are revealed. The highest-value bidder, convinced that a bid b is enough to win the

[8] Think of the hypothetical example of an auction in which the winner is determined randomly through a gamble (actually this form of allocating the frequencies was really used by FCC before it started selling the licenses through the auctions). In case of such a random auction the reduction of costs does not increase the probability of winning at all.

auction, might be outbid by a lower-value bidder, who decided to bid more aggressively.

But in case of the so called private-value auctions[9] the first-price sealed-bid auction can be shown to lead to the higher expected value of seller's revenues (lower expected value of the buyer's costs) than the English auction. One of the reasons for this is risk-aversion. In the English auction the bidding ends when all but the last bidder withdraw from the auction. The winner pays the price at which the second-best bidder quits, as facing no competition he does not have to augment it any further. In some cases this price could be much lower than the winner's maximal willingness to pay. In the first-price sealed-bid auction on the other hand the highest-value bidder does not know what price is enough to win, and so being risk averse he might bid much higher than needed[10].

Of course the decision problem of which auction design to use is very often much more complicated in reality, especially in case of multi-unit auctions, or when there is a serious risk of collusion among bidders.

5. Designing an efficient auction

A huge part of auction literature concentrates on comparisons of efficiencies and expected revenues of different auction designs. The statement that the English auction always leads to the efficient outcomes was of course an oversimplification. First, the ascending-bid mechanism is just a small part of the whole design. Apart from that, the auctioneer has to decide about many other elements: the level of the reserve price, the entry costs, the minimal increment, the amount of the information revealed, and so on, all of which influence both the efficiency and the level of revenues. Second, in case of the multi-unit auctions there exist many variants of the English auction, e.g. the clock auction, or the simultaneous multiple round ascending auction. Third, the situation complicates even further in case of combinatorial auctions, where the determination of the winner becomes a nontrivial problem itself[11]. When package bidding is allowed the English auction mechanism complicates even more, and can have the form of a ascending proxy auction, or clock-proxy auction[12].

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[9] In such auctions the valuations of the bidders are independent, i.e. each bidder attributes a certain value to the object, which is not dependent on the valuations of others.

[10] This of course is not a formal demonstration of this fact. For such, look at any book on auction theory, for instance V. Krishna, op.cit., or check the summary in P.R. McAfee, J. McMillan, *Auctions and Bidding*, "Journal of Economic Literature" 1987, Vol. 25, p. 699-738.

[11] In the combinatorial auctions the participants can make bids both for individual objects and for the packages of few objects. It has been proven that the winner determination problem in this situation is NP-complete, meaning that the polynomial-time algorithm that is guaranteed to compute the optimal allocation is unlikely to exist. For more on this see: *Combinatorial Auctions*...

[12] *Combinatorial Auctions*...

The analyses of efficiency are carried out both theoretically and experimentally. Theoretical papers analyze how different rules of auction design affect the efficiency under various market situations, e.g. asymmetries among the market participants, uncertainty, risk of collusion or corruption, and so on. The comparison of efficiencies of different market institutions using empirical data is very complicated, as it is generally impossible to reach the information of the true valuations of the object for the bidders, which are needed to analyze the efficiency issues. Johnson [1979] used an interesting test of efficiency which evaded the problem: when comparing the English auction and first-price sealed-bid auction results in case of timber-right auctions, he looked how many of them were followed up by a resale. The assumption was that a resale indicates inefficiency. The results he obtained confirmed the lower efficiency of the first-price sealed-bid auctions. Of all 379 transactions analyzed there were 7 followed by a resale, and all of them took place in case of the first-price sealed-bid auction[13].

Nevertheless the analyses of the efficiency of market institutions are typically hard to carry out using empirical data, if only for the inability to meet the *ceteris paribus* assumption, enabling for the comparison of data. Because of this, for these purposes the laboratory experiments are usually used. The examples of such studies are numerous. For instance [Cason, Friedman, 2008] compare the efficiencies of the four most commonly applied double auction mechanisms: continuous double auction, single call market, uniform price double auction, and multiple-call market, reaching a conclusion that the most efficient is the first one[14]. Thomas and Wilson [2002] analyze the efficiency of multilateral negotiations, and compare it with the efficiency of a standard first-price sealed-bid auction[15]. Their conclusions were that the efficiency in case of multilateral negotiations was only slightly higher[16].

As the tradeoff between efficiency and revenue maximization goals does exist, an important task is not only to state whether a mechanism is efficient or inefficient, but also to measure the scale of the inefficiency. The efficiency is typically measured as the amount of surplus obtained in an auction, divided by the total surplus. An efficiency measured in this way may of course turn out to be much higher, than a mere indicator of the percentage of auctions won by the highest-value bidder. For example in the author's analyses of the efficiency of the first-price sealed-bid auction

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[13] R. Johnson, *Oral Auction Versus Sealed Bids: An Empirical Investigation*, "Natural Resources Journal" 1979, Vol. 19, No. 2, p. 315-335. The summary of other results of tests of some auction theory hypotheses using empirical data can be found in P.R. McAfee, J. McMillan, op. cit.

[14] T.N. Cason, D. Friedman, *A Comparison of Market Institutions*, "Handbook of Experimental Economics Results", Vol. 1, ed. Ch. Plott, V. Smith, North-Holland, Amsterdam, 2008, p. 264-272.

[15] Ch. J. Thomas, B.J. Wilson, *A Comparison of Auctions and Multilateral Negotiations*, "RAND Journal of Economics" 2002, Vol. 33, No. 1, p. 140-155.

[16] For more on the utilization of experiments in the analyses of auction designs' efficiencies see: P. Kuśmierczyk, *Wykorzystanie eksperymentów do badania efektywności systemów aukcyjnych*, Prace Naukowe UE we Wrocławiu nr 64, "Ekonomia 1", Wyd. Uniwersytetu Ekonomicznego we Wrocławiu, Wrocław 2009, p. 97-107.

and first-price sealed-bid auction with additional negotiations (unpublished)[17] about 14% of all auctions ended up inefficient (i.e. the auction was not won by the highest-value bidder), but the efficiency of the first-price sealed-bid auction turned out to be 99.08%, and the efficiency of the first-price sealed-bid auction with additional price negotiations was 99.43%[18].

A very important benefit of the laboratory experiments is that they can be used to solve practical problems, i.e. help tailor the auction rules to the specific market situation, so as to reach the efficiency goal (and also typically maximize the seller's revenues). The experiments were used for this purpose in case of many FCC auctions, or in case of UMTS auction in the United Kingdom. All of those auctions ended up with huge successes. The laboratory tests were also recently run in the United States to help prepare the rules of a troubled assets reverse auction. Its introduction was considered as a part of a bailout plan[19].

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[17] For the description of the experiments and results of the revenue comparison see: P. Kuśmierczyk, *First-Price Sealed-Bid Auction with Additional Price Negotiations: Theoretical Analyses and Results of Experiments*, [in:] *Global Challenges and Policies of the European Union – Consequences of the 'New Member States'*, ed. M. Piotrowska, L. Kurowski, Research Papers of Wrocław University of Economics, Publishing House of Wroclaw University of Economics, Wroclaw 2009, p. 269-277.

[18] The value of the efficiency parameters depends on the distribution of bidders' values, on their number, and so on. If the different bidders' valuations are close to each other, then, even if the auction does not end up with an efficient allocation, the loss in total surplus is not substantial.

[19] For more on those auctions see: P. Kuśmierczyk, *Wykorzystanie eksperymentów...*

EFEKTYWNOŚĆ EKONOMICZNA JAKO JEDEN Z GŁÓWNYCH CELÓW W PRZYPADKU AUKCJI

Streszczenie: Mechanizm aukcyjny znajduje zastosowanie w przypadku rynków płytkich, o małej liczbie nabywców bądź sprzedających. Aukcje zmuszają uczestników do silnej konkurencji, pozwalając ich organizatorom na osiągnięcie wysokich przychodów, bądź w przypadku przetargów na zminimalizowanie kosztów. Jednak wielu ekonomistów dowodzi, że najważniejszym celem aukcji jest zapewnienie efektywności ekonomicznej, przez którą rozumie się alokację dóbr do tych podmiotów, dla których mają one największą wartość.

Artykuł analizuje pojęcie efektywności ekonomicznej i przedstawia argumenty na poparcie tezy, że jest ona istotnym celem przy przeprowadzaniu aukcji. Pokazuje także, że efektywność aukcji zależy w dużej mierze od przyjętych reguł aukcyjnych. Eksperymenty laboratoryjne okazują się być pomocne przy ich projektowaniu.