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On the choice of obtaining and disclosing the common value in auctions ☆

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ABSTRACT

This paper introduces a game-theoretic analysis of auction settings where bidders' private values depend on an uncertain common value, and the auctioneer has the option to purchase information that can eliminate that uncertainty. Therefore the auctioneer needs to decide whether to purchase the information, and if so, whether to disclose it to the bidders. Unlike prior work, the model assumes that bidders are aware of the auctioneer's option to purchase the external information but are not necessarily aware of her decision. The modeling of the problem as a Stackelberg game, where the auctioneer is the leader, is complicated by the fact that in cases where the auctioneer decides not to disclose the information, the situation is actually modeled as a version of Stackelberg game where the follower has potentially imperfect information about the leader's actions. Our analysis of the individual expected-benefit-maximizing strategies results in the characterization of the pure-strategy perfect Bayesian Nash equilibrium and proof of its existence for any setting. In addition, we introduce an algorithm for extracting the equilibrium as a function of the information cost, which is of great importance when the information is provided by a strategic information-provider. The analysis is also extended to deal with mixed-strategy perfect Bayesian Nash equilibrium and with noisy information. Overall, the analysis enables the demonstration of various model characteristics, including many non-intuitive properties related to the benefits of competition, the benefits in having the option of the auctioneer to purchase such information and the benefits encapsulated in the bidders' awareness of such an option.

1. Introduction

Recent advances in information technologies support the emergence of dynamic pricing mechanisms as the successors of fixed pricing in electronic marketplaces. The success of dynamic pricing mechanisms is based on their premise to improve benefit and resource utilization. One important dynamic pricing mechanism, where price emerges from the buyers' (e.g., bidders') willingness to pay, is auctions. Over the past two decades, auctions have become an integral part of electronic commerce, a popular method for transacting business, and a promising field for applying agent and Artificial Intelligence technologies [30,65,37,59,56].

The key aspect that affects bidding in an auction is the way the bidders value the auctioned item. In this paper we consider an auction model where the auctioned item is characterized by an uncertain common value, on which bidders'

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private values are based [34,22,23,40]. For example, consider an auction for the lease of an advertising space in a shopping mall. Here, the common value associated with the advertising space is the foot traffic (e.g., number of shoppers that visit the shopping mall in a certain period of time). Each bidder's (i.e., potential advertiser) valuation of her expected benefit from leasing the advertising space depends on the foot traffic. Moreover, since each bidder has a different benefit from having a single shopper see its ad, different bidders will have different valuations for different values of the foot traffic. Another example is the classic oil drilling case [34]. Here, the amount of oil and the depth of its location under the ground are the uncertain common values. However, each bidder's valuation of the benefit from owning the drilling rights depends on the stratum to which she needs to drill, as each bidder can have different equipment and drilling technology. Similar arguments favoring this hybrid-value model can be suggested for other classic auction domains, e.g., the U.S. Federal Communications Commission (FCC) [11]. Even the classic painting example that is often used in the context of private value can be considered as an example for the hybrid model due to the resell factor [22].

One key question in models assuming an uncertain common value concerns the disclosure of information that may eliminate some of the uncertainty associated with the common value, whenever such information is available to the auctioneer. Unlike prior work that considered models combining private and common value aspects [22,23,9,40], bidders in our model are not limited to an additive combination of the two, and the effect of the common value on all bidders' valuation is not necessarily positively correlated. One important implication of this difference is that, in contrast to results obtained in prior work [51], the preferred choice for the auctioneer is not necessarily to always disclose the common value. Instead, the auctioneer needs to selectively disclose the information regarding the common value, based on her beliefs regarding the bids that will be received for any value disclosed and whenever not disclosing any value.

In many real-life situations the auctioneer does not initially possess the information, but rather needs to pay in order to obtain it (either in the form of resources it needs to spend in order to produce it "internally" or in the form of purchasing it from an external information-provider). Taking the examples above, information concerning shoppers' traffic can be obtained either by placing mall employees next to the offered space in order to measure the bypassing traffic, by analyzing data collected from the security cameras, by executing a statistical analysis based on the number of people visiting the shopping mall or by hiring an expert that can produce such an estimate using her own methods. In the oil drilling example the auctioneer can execute an exploratory drill or alternatively pay a specialist for a thorough survey of the field. Our model applies to this case by enabling the option of purchasing information that fully eliminates the uncertainty associated with the common value of the auctioned item. This option is available only to the auctioneer. Bidders in our model have no such option of purchasing the information (for various realistic reasons, e.g., if the production of the information requires access to some data that only the auctioneer has) however become acquainted with the true common value if the auctioneer purchases the information and chooses to disclose the value received. In such a setting, a substantial part of the auctioneer's strategy is deciding whether or not to obtain the external information, and, if so, once obtained, whether or not to disclose it to the bidders. The problem can thus be modeled as a Stackelberg game where the auctioneer is the leader and the followers are the bidders. This modeling is complicated by the fact that in cases where the auctioneer decides not to disclose the information, the situation is actually modeled as a version of a Stackelberg game where the followers have potentially imperfect information about the leader's actions.

The contributions of this paper are threefold: First, the paper formally presents and analyzes an auction model where: (a) bidders' valuations depend on an uncertain common value in a general way; (b) the auctioneer can eliminate the uncertainty associated with the common value through the purchase of information; and (c) bidders are aware of the availability of such an option to the auctioneer. To the best of our knowledge, a model of this type has not been investigated to date. In particular, the incorporation of costly information and bidders' awareness results in several complexities both from the strategy space and the analysis points of view. The analysis given essentially derives from the individual benefit-maximizing strategies of the auctioneer (given the bidders' belief regarding whether or not the auctioneer is planning to purchase the information and which values she will disclose) and the bidders (given the auctioneer's decision of whether to purchase the information and which values she is planning to disclose). This leads to the characterization of stable solutions and a perfect Bayesian Nash equilibrium. As part of the analysis we characterize the influence of the cost of obtaining the information over the equilibrium and the resulting expected benefit of the different players, proving, among other things, that an equilibrium always exists. The analysis leads to an algorithm for calculating the pure-strategy equilibrium for all different possible costs of purchasing the information, which is of much importance for the auctioneer and the social planner. The analysis encompasses various other aspects of the model, such as the expected-benefit-maximizing strategy for a self-interested information-provider and the effect of bidders' homogeneity over the results.

Second, using the equilibrium analysis, we manage to illustrate various properties of the model. The nature of these results is primarily existential (i.e., showing the existence of said solution), and many of them are somehow counter-intuitive. For example, it is demonstrated that, in conflict with classic auction theory, the auctioneer will not necessarily find it beneficial to have more bidders participate in the auction and similarly bidders will not necessarily prefer less competition. Also, bidders' unawareness of the auctioneer's option to purchase the information does not necessarily play into the hands of the auctioneer and, similarly, bidders may sometimes benefit from not knowing that the auctioneer has the option to purchase such information. Furthermore, having the option to purchase the information can be devastating for the auctioneer in some settings, even though she gets to decide whether or not to purchase the information and what portions of it to disclose to the bidders. Similarly, the auctioneer may prefer that the information be offered at a high rather than a low price (and in many cases would even prefer costly information over the option to obtain it for free). Common to all the