Solving Winner Determination Problems for Auctions with Economies of Scope and Scale

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Abstract. Economies of scale and scope describe key characteristics of production cost functions that influence allocations and prices on procurement markets. Auction designs for markets with economies of scale are much less well understood than combinatorial auctions, they require new bidding languages, and the supplier selection typically becomes a hard computational problem. We suggest a bidding language for respective markets, and conduct computational experiments to explore the incremental computational burden to determine optimal solutions brought about by the need to express economies of scope for problems of practical size.

Keywords: volume discount auctions, procurement auctions, economies of scale, economies of scope.

1 Introduction

This paper is motivated by real world procurement practices of an industry partner, where procurement managers need to purchase large volumes of multiple items. Typically, in these circumstances, economies of scale are jointly present with economies of scope. For example, suppliers that set up a finishing line for a certain product have high setup costs, but low marginal cost leading to a unit price degression. Economies of scope often arise in shipping and handling a larger number of items to a customer.

State of the practice in markets with economies of scale are split-award contracts, where the best bidder gets the larger share of the volume for a particular quantity and the second best bidder gets a smaller share (e.g., a 70/30% split). With significant economies of scale, suppliers face a strategic problem in these auctions, since there is uncertainty about which quantity they will get awarded, they might speculate and bid less aggressive based on the unit cost for the smaller share. In other words, split award auctions do not allow suppliers do adequately express economies of scale.

2 Bid Language

Our bid language describes the types of bids that can be submitted and is motivated by real-world business practice. We suggest tiered bids, a bid language where suppliers

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submit unit prices that are valid for continuous intervals of the volume of items purchased. In contrast to Davenport and Kalagnanam [1] the quantity purchased determines a unit price that is valid for the entire quantity.

In addition, the suppliers can indicate rebates of the form: "If you buy a quantity of more than x units of various items you will receive an additional rebate of y". This allows bidders to express economies of scope that span more than one item. Additionally bidders often specify these kinds of rebates out of strategic considerations, in order to secure a share of the market.

3 Computational Complexity of the Supplier Selection

While the bid language leads to much flexibility for the suppliers in specifying discounts and rebates in a compact format, it also incurs computational complexity on the buyer's side. We show that the problem is weakly NP-complete and explore the empirical hardness of the supplier selection problem if solved exactly with a branch-and-bound approach. The supplier selection process should be used in an interactive manner exploring different award scenarios and side constraints. The process is sometimes refered to as scenario analysis. Therefore, the experiments focused on solver times of up to an hour.

The results are based on a large set of experiments with real and synthetic bid data. The synthetic bid data follows the characteristics that we found in real-world bid data. We observed that, with tiered bids but without rebates, the optimal solution was found in a matter of minutes for problem sizes of up to 12 suppliers, 24 items, 4 tiers, and 5 rebate schedules. Adding 8 discount tiers will often lead to solution times of several hours. The results provide an understanding which problem sizes can be solved optimally in an interactive decision support tool.

Reference

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