Distributional Robustness: From Pricing to Auctions

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We study robust mechanism design for revenue maximization when selling a single item in an auction, assuming that only the mean of the value distribution and an upper bound on the bidders' valuations for the item are known. Robust mechanism design is a rising alternative to Bayesian mechanism design, which yields designs that do not rely on assumptions like full distributional knowledge, but rather only partial knowledge of the distributions. We seek a mechanism that maximizes revenue over the worst-case distribution compatible with the known parameters. Such a mechanism arises as an equilibrium of a zero-sum game between the seller and an adversary who chooses the distribution, and so can be referred to as the max-min mechanism.

Carrasco et al. [2018] derive the max-min pricing when the seller faces a single bidder for the item. We go from max-min pricing to max-min auctions by studying the canonical setting of two i.i.d. bidders, and show the max-min mechanism is the second-price auction with a randomized reserve. We derive a closed-form solution for the distribution over reserve prices, as well as the worst-case value distribution, for which there is simple economic intuition. We also derive a closed-form solution for the max-min reserve price distribution for any number of bidders, and we show that unlike the case of two bidders, a second-price auction with a randomized reserve cannot be an equilibrium for more than two bidders.

Our technique for solving the zero-sum game is quite different than that of Carrasco et al. – we focus on a reduced zero-sum game, where the seller can only choose a distribution for a second-price auction with a randomized reserve price (rather than any mechanism). We then analyze a discretized version of the setting to find conditions an equilibrium would satisfy. By refining the discretization grid, we are able to achieve differential equations, and solving them yields closed-form non-discretized distributions. The resulting distributions for the seller and the adversary are later shown to be an equilibrium for the reduced zero-sum game. For the two-bidder case, we expand our result to an equilibrium of the original zero-sum game, where the seller is not limited to second price auctions with reserve.

The full version of the paper is available at https://arxiv.org/abs/2205.09008.

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Additional Key Words and Phrases: revenue maximization, robust mechanism design, max-min optimality

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