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Price instability in multi-unit auctions

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Abstract

We consider a uniform-price procurement auction with indivisible units and private independent costs. We find an explicit solution for a Bayesian Nash equilibrium, which is unique if demand shocks are sufficiently evenly distributed. The equilibrium has a price instability in the sense that a minor change in a supplier's realized cost can result in a drastic change in the market price. We quantify the resulting volatility and show that it is reduced as the size of indivisible units decreases. In the limit, the equilibrium converges to the Supply Function Equilibrium (SFE) for divisible goods if costs are common knowledge.
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1. Introduction

Many procurement auctions trade indivisible units or have bid constraints that force suppliers to offer their goods with stepped supply functions. Such markets often have unpredictable and significant price variations even if demand is certain and costs are common knowledge (or have small variations). Similar to von der Fehr and Harbord (1993), we refer to this as

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a price instability. One illustrative example is the Bertrand–Edgeworth game, where capacity-constrained suppliers compete on prices and each supplier is paid its own price (Edgeworth, 1925; Kruse et al., 1994; Deneckere and Kovenock, 1996).[1] Another illustrative example is the related model of a uniform-price auction by von der Fehr and Harbord (1993). In the Nash equilibrium of both models, each supplier has positive mark-ups and chooses offers randomly to avoid a situation where the best response of a rival is to slightly undercut the supplier.[2] In both models, a supplier offers its entire production capacity at one price. In this paper we are the first to analyse price instability in markets where each supplier has multiple indivisible units and is allowed to offer each unit at a different price. We focus on procurement auctions, but results are analogous for sales auctions.

We generalize von der Fehr and Harbord's model by considering a uniform-price auction where each supplier offers a number of indivisible units at different prices. Another generalisation is that we allow suppliers to have private and independent costs. Producers are symmetric ex-ante, before they receive information about their cost. The sequence is such that each supplier receives a signal of its cost and then chooses an offer price, with higher signals leading to higher prices. As illustrated in Fig. 1, this gives rise to an offer price range for each indivisible unit of the supplier. We solve for a pure-strategy Bayesian NE, where each supplier chooses offer prices for each of its units in order to maximise its expected profit given its private information. We show that if the cost uncertainty is sufficiently small and either indivisible units are sufficiently small or demand shocks are sufficiently evenly distributed, then there exists one symmetric pure-strategy Bayesian Nash equilibrium where the offer price ranges for the different units of a supplier will not overlap, as illustrated in Fig. 1. We call this property *step separation*. We explicitly solve for the symmetric equilibrium and prove that it is the unique equilibrium if demand shocks are sufficiently evenly distributed. In the special case with two units per supplier, we also analyze NE where offer ranges of units overlap, as can occur with highly non-uniformly distributed demand shocks. Overlapping offer prices for non-overlapping marginal costs leads to welfare losses.

For circumstances with small indivisible units and small cost uncertainties, we show that the standard deviation of a supplier's equilibrium offer is approximately given by $(I-1)(p_n-c_n)/(\sqrt{12}n)$, where I is the number of symmetric suppliers and $p_n - c_n$ is the approximate mark-up for the n'th unit (the n'th cheapest unit of a supplier). For parameter values that are typical in a wholesale electricity market, this approximation would imply that the standard deviation in the offer for the most expensive production unit is in the range 0.2%–5% of the reservation price. Our analysis indicates that bid volatility should be less pronounced for less expensive production units. We also estimate the standard deviation of the market price (price instability) for each demand level. It can be 0.1%–3% of the reservation price for the highest demand level and tends to be smaller for lower demand levels.

In the limit where costs are common knowledge, our Bayesian NE with price instability corresponds to a mixed-strategy NE in accordance with the purification theorem (Harsanyi, 1973). We let the size of indivisible units decrease to show that the mixed-strategy NE converges to the supply function equilibrium (SFE); a pure-strategy NE in a market with divisible goods which was originally characterized by Klemperer and Meyer (1989). The convergence result confirms a conjecture made by Newbery (1998) and gives theoretical support to the use of SFE to approx-

[1] In Bertrand–Edgeworth games, price instability means that suppliers sell goods at different prices, which violates the law of one price. This phenomenon is sometimes called price dispersion (Varian, 1980).

[2] In case firms choose prices sequentially as in a dynamic Bertrand game, then they can undercut each other sequentially, which will give rise to Edgeworth price cycles (Maskin and Tirole, 1988; Noel, 2007).

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