Journal of Econometrics 180 (2014) 198–216

Contents lists available at ScienceDirect

Journal of Econometrics

journal homepage: www.elsevier.com/locate/jeconom

Inference of bidders' risk attitudes in ascending auctions with endogenous entry☆

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ARTICLE INFO

Article history:
Received 20 April 2012
Received in revised form
21 January 2014
Accepted 24 February 2014
Available online 31 March 2014

JEL classification:
D44
C12
C14

Keywords:
Ascending auctions
Risk attitudes
Endogenous entry
Tests

ABSTRACT

Bidders' risk attitudes have key implications for the choices of revenue-maximizing auction formats. In ascending auctions, bid distributions do not provide information about risk preference. We infer risk attitudes using distributions of transaction prices and participation decisions in ascending auctions with entry costs. Nonparametric tests are proposed for two distinct scenarios: first, the expected entry cost can be consistently estimated from the data; second, the data does not report entry costs but contains exogenous variation in potential competition and auction characteristics. We also show the identification of risk attitudes in ascending auctions with selective entry, where bidders receive entry-stage signals correlated with their values.

1. Introduction

We propose nonparametric tests to infer bidders' risk attitudes in ascending (or open out-cry) auctions with endogenous entry. In these auctions, potential bidders observe some entry costs, e.g., bid preparation/submission costs and/or information acquisition costs, that they need to incur before learning private values and decide whether to pay the costs to be active in the bidding stage. Bidders make rational entry decisions by comparing expected utility from entry with that from staying out, based on their knowledge of entry costs or preliminary signals of private values to be realized in the subsequent bidding stage.

Inference of bidders' risk attitudes has important implications for sellers' choices of the revenue-maximizing auction format. When the participation of bidders is exogenously given and fixed, the Revenue Equivalence Theorem states that expected revenues from first-price and ascending auctions are the same if bidders are risk-neutral in an environment with symmetric independent private values (IPV). If bidders are risk-averse, however, Matthews (1987) showed that in such environments first-price auctions yield higher expected revenues than ascending auctions. Bidders' risk attitudes also affect revenue rankings among symmetric IPV auctions when participation decisions are endogenous. For risk-neutral bidders, Levin and Smith (1994) showed that any given entry cost induces the same entry probabilities in first-price auctions (with each entrant observing the number of the other entrants) and in ascending auctions. Thus the Revenue Equivalence Theorem implies that expected revenues must be the same from both first-price and ascending formats under endogenous entry. On the other hand, Smith and Levin (1996) established the revenue ranking of first-price over ascending auctions under endogenous

☆ We are grateful to the Associate Editor and four anonymous referees for constructive comments. We also thank Dan Ackerberg, Federico Bugni, Xu Cheng, Flavio Cunha, Ken Hendricks, Tong Li, Isabelle Perrigne, Frank Schorfheide, Steven Stern, Petra Todd, Quang Vuong and seminar/conference participants at Berkeley, Carnegie Mellon, Michigan, Northwestern, Pennsylvania, Toronto, Virginia, Wharton, North American Econometric Society Summer Meetings (St. Louis 2011) and Society of Economic Dynamics Annual Meetings (Ghent 2011) for helpful comments and suggestions. All remaining errors are our own.

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http://dx.doi.org/10.1016/j.jeconom.2014.02.010
0304-4076/

entry for risk-averse bidders, except for the case with decreasing absolute risk aversions (DARA).[2]

While some earlier papers had studied the identification and estimation of bidders' risk attitudes in *first-price* auctions (e.g. Bajari and Hortacsu (2005), Campo et al. (2011) and Guerre et al. (2009)), inference of risk attitudes in ascending auctions remains an open question. Athey and Haile (2007) point out that bidders' risk attitudes cannot be identified from bids *alone* in ascending auctions where participation is given exogenously. This is because bidding one's true value is a weakly dominant strategy in ascending auctions, *regardless of bidders' risk attitudes*. Thus, bidders with various risk attitudes could generate the same distribution of bids in Bayesian Nash equilibria. The distribution of bids from entrants alone is therefore not sufficient for inferring bidders' risk attitudes.

In this paper, we propose tests for bidders' risk attitudes based on transaction prices *and* entry decisions under two empirically relevant data scenarios. In the first scenario, we assume that the data has information that allows researchers to consistently estimate the expectation of entry costs, and in the second scenario, we assume that the data does not provide any information about the level of entry costs, but does contain the variation in the number of potential bidders and some auction-level heterogeneity. In both cases, we show how to relate the distribution of transaction prices and entry decisions to the underlying risk attitudes nonparametrically.

In the first scenario, considered in Section 4, we require that the data contains some noisy measures of entry costs so that the mean of entry costs in the data-generating process can be consistently estimated. This is motivated by the fact that entry costs are often measurable (at least up to some noise) in applications. Examples of entry costs include bid preparation costs (e.g., mailing costs), admission fees or other information acquisition expenses, which are often reported in the data with noise.

The main insight for our test in this scenario can be illustrated using the mixed-strategy entry model (which is analogous to that considered in Levin and Smith (1994) for first-price auctions with risk-neutral bidders). In the entry stage, all potential bidders observe a common entry cost and decide whether to pay the cost and enter an ascending auction in the bidding stage. In a mixed strategy Nash equilibrium in the entry stage, potential bidders' participation in the auction will be in mixed strategies with the mixing probability determined to ensure that a bidder's *ex ante* expected *utility* from entry equals that from staying out. Hence bidders' risk attitudes can be identified by comparing the expected *profits* from entry with its certainty equivalent. As long as the expectation of entry costs can be identified from the data, the distribution of transaction prices and entry decisions alone can be used to make such a comparison.

We apply the analog principle to construct a non-parametric test statistic, using observations of transaction prices and entry decisions as well as estimates of the mean of entry costs. We characterize the limiting distribution of this statistic and propose a bootstrap test that attains the correct asymptotic level and is consistent under any fixed alternative of risk-aversion or risk-loving.

In the second scenario, considered in Section 5, we assume that the data does not provide information about the level of entry costs, but does contain some auction-level heterogeneity (such as some characteristics of the auctioned object) and the variation in the numbers of potential bidders. We propose a nonparametric test for risk-aversion for this case, under the assumption that the variation in potential competition is exogenous (in the sense that it does not alter the marginal distribution of private values once conditional on the observed auction features). Refraining from parametric restrictions on how observed auction features change the distribution of private values, we formalize how risk attitudes determine entry probabilities under various auction features and potential competition. Our test is based on the idea that the curvature of utility functions affects how the ratios between the changes in bidders' interim utilities compare with the ratios between the changes in expected private values, under different pairs of observed auction features. The main finding is that, even if entry costs are unreported in data, we could relate these two ratios to the observed distributions of transaction prices and entry decisions, by exploiting the variation in auction features and the number of potential bidders. We provide encouraging Monte Carlo evidence for the finite-sample performance of our test.

In Section 6, we discuss possible extensions of our tests by removing two of the key assumptions. First, we show that when bidders' values are affiliated, it is possible to derive testable implications for risk attitudes using existing results on the sharp bounds for the surplus of risk-neutral bidders in ascending auctions (Aradillas-Lopez et al., 2013). Second, we show that if entry is selective (e.g., when potential bidders observe signals correlated with private values to be drawn in the bidding stage), then the idea of testing risk attitudes through the identification of risk premium applies, provided that the data contains continuous variation in observed entry costs.

It is worth noting that by "inference of risk attitudes" we mean to make a data-supported conclusion about whether bidders' utility functions are concave, linear or convex. We do not address the question of how to recover the utility function completely over its domain, which is left for future research.

The remainder of the paper is structured as follows. In Section 2 we discuss the related literature; in Section 3 we present the model of ascending auctions with endogenous entry; in Sections 4 and 5 we describe the theoretical results for our tests under two data scenarios and discuss the inference using proposed test statistics; in Section 6 we discuss how to extend our test to auctions with selective entry or affiliated private values; and in Section 7 we conclude. Proofs are collected in the Appendix.

2. Related literature

This paper contributes to two branches of the literature on structural analyses of auction data. The first branch includes papers that analyze the equilibrium and its empirical implications in auctions with endogenous entry and *risk-neutral* bidders. These include Levin and Smith (1994), Li (2005), Ye (2007) and Li and Zheng (2009). Marmer et al. (2013) study a model of first-price auctions with risk-neutral bidders and selective entry, and discuss testable implications of various nested entry models. Roberts and Sweeting (2010) estimate a model of ascending auctions with selective entry and risk-neutral bidders. Gentry and Li (2014) provide partial identification results for ascending auctions with risk-neutral bidders when entry is selective. They derive sharp bounds on the distribution of private values conditional on signals, using the variation in factors that affect bidders' entry behaviors (such as the number of potential bidders and entry costs). They also apply these results to bind counterfactual seller revenues under alternative auction rules. Aradillas-Lopez et al. (2013) provide

[2] Even in the case with DARA, first-price auctions yield higher expected revenues than ascending auctions when entry costs are low enough. To see this, consider a simple case where entry costs are low enough so that the difference between entry probabilities in first-price and ascending auctions is sufficiently small. In such a case, these two probabilities are both close to 1 and only differ by some small $\varepsilon > 0$. By Matthews (1987), conditioning on any given number of entrants, ascending auctions have smaller expected revenues than first-price auctions. When the difference between the two entry probabilities is small enough, such a revenue ranking result is preserved.