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Are there common values in first-price auctions? A tail-index nonparametric test☆

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ABSTRACT

We develop a consistent nonparametric test of common values in first-price auctions and apply it to British Columbia Timber Sales data. The test is based on the behavior of the CDF of bids near the reserve price. We show that the curvature of the CDF is drastically different under private values (PV) and common values (CV). We then show that the problem of discriminating between PV and CV is equivalent to estimating the lower tail index of the bid distribution. Our approach admits unobserved auction heterogeneity of an arbitrary form. We develop a Hill (1975)-type tail index estimator and find the presence of common values in BC Timber Sales.

1. Introduction

Economists have long recognized that auctions with common values (CV), where buyers do not know in advance their willingness to pay, are very different from auctions with private values (PV). For example, a theoretical result of Milgrom and Weber (1982) shows that in the affiliated value model that allows for both common and private components in bidder valuations, an open auction is revenue superior to the first-price, sealed-bid auction.[1] Other policy recommendations differ depending on whether the values are private or common.[2] For example, in a CV environment, the seller may decide to reveal information to mitigate the winner's curse effect. Another concrete example is setting the optimal reserve price. Our application in this paper is to British Columbia Timber Sales (BCTS). In British Columbia, the Ministry of Forests has developed a complex system of reserve prices with the goal of maximizing revenue for the government. As the optimal reserve price setting depends on the employed model, it is important to know whether a private or common value model is more appropriate in this application.

This paper develops a consistent (asymptotic power-one) tail-index nonparametric test for common or private values in first-price auctions and applies it to timber auctions in British Columbia. This is the first paper we are aware of that uses powerful methods from the econometric literature on extremes to shed light on an important problem in empirical industrial organization.

The approach in this paper is inspired by Hendricks et al. (2003) who utilize a result in Milgrom and Weber (1982) to show that the

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[1] There is also empirical evidence to the importance of this effect, e.g. in Shneyerov (2006).

[2] In addition, as Laffont and Vuong (1996) have shown, models with common values are often nonparametrically non-identified, while private-value models are often identified.

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behavior of bids around the reserve price is different under PV and CV.[3] Specifically, the lower bound of the support of the so-called pseudo-values (see Guerre et al., 2000) is equal to r under PV but is strictly greater than r under CV. We show that under PV, there must be more clustering of bids near the reserve price than under CV. For *independent* private values, an excessive clustering result was previously obtained by Guerre et al. (2000) in the context of value density estimation. However, the previous literature has not considered a formal statistical test of PV versus CV based on the behavior of bids near the reserve price.

Our innovation is to develop such a test based on the *tail index* of the bid distribution. In our application, the tail index gives a measure of bid clustering around the reserve price. The tail index characterizes the curvature or rate of decay of a CDF in the tail, and is a popular approach to modeling extreme quantiles in economics, finance, insurance and engineering. See Section 2 for a formal definition, and see Embrechts et al. (1997), Gabaix (2008) and Davis (2010) for a review on power tails and their applications. We show that the tail index κ is equal to 1 under CV, and is equal to $1/2$ under PV. Under private values, Guerre et al. (2000) establish this result only for the IPV case. We show that the tail index is $1/2$ whether the private values are independent or affiliated.[4]

To our knowledge, existing tests for common values take the null hypothesis to be that of private values (independent or affiliated) and the alternative to be a model with a common value component. In many applications, however, there is no paradigm (PV or CV) that is generally "accepted". By switching the null and alternative hypotheses, this paper is the first to propose a test of the null hypothesis that incorporates a CV component versus a PV alternative.

Milgrom and Weber (1982)'s classic model has been fundamental widely in both theoretical and empirical research on auctions, despite the fact that it applies only to the symmetric environment. Empirical applications within a symmetric common-value paradigm include Paarsch (1992) to auctions for tree-planting contracts, Haile (2001) to timber sales, Hong and Shum (2002) to highway procurement, Hendricks et al. (2003) to off-shore oil, and Shneyerov (2006) to municipal bonds. Within the symmetric private-value paradigm, applications include Laffont and Vuong (1996) to eggplant auctions in Marmande (France), Krasnokutskaya (2011) to highway procurement, and Li and Perrigne (2003) to timber sales.

However, it is indisputable that bidder asymmetries are important in a number of markets. For example, in a seminal paper, Hendricks and Porter (1988) emphasize bidder asymmetries in sealed-bid auctions for off-shore drainage tracts. Also, within the private-value paradigm, Bajari and Ye (2003) and Jofre-Bonet and Pesendorfer (2003) have studied auctions for highway procurement, Campo et al. (2003) have considered off-shore oil auctions, Flambard and Perrigne (2006)—auctions of snow-removal contracts, while Athey et al. (2011) emphasize asymmetries in timber sales. A question then arises, to what extent is our tail-index approach robust to bidder asymmetries. We consider a class of asymmetric models in which, as we show, the tail index is preserved.

The estimation of the tail index is a well-studied problem in statistics and econometrics, see Hill (1975), Hsing (1993) and more recently Hill (2010, 2011b). We employ a version of Hill's (1975) celebrated estimator $\hat{\kappa}$ of the tail index. The estimator is consistent and asymptotically normal, and is remarkably easy to implement for a one-sided t-test of PV versus CV. Our test approach works even when there is unobserved auction heterogeneity, and even if the number of potential bidders is unobservable.[5] Further, since Hill's (1975) estimator $\hat{\kappa}$ exhibits the same stochastic properties under either hypothesis PV and CV, differing only in the asymptotic mean, our test of CV or PV is consistent: it obtains an asymptotic power of one against the chosen alternative.

An early approach to testing for common values was to check if bids increase monotonically with the number of potential bidders; a non-monotonic pattern was believed to provide evidence of common values. This approach was initiated by Gilley and Karels (1981), and applied to second-price sealed-bid and English auctions by Paarsch (1991) and Bajari and Hortaçsu (2004). However, Pinkse and Tan (2005) have shown that in first-price auctions, this pattern can also arise if values are private and affiliated.

The first paper that adopted a structural approach to this problem is Paarsch (1992), where a parametric testing method is developed and applied to the auctions of tree planting contracts in BC. The recent literature has focused on nonparametric approaches. Haile et al. (2003) have proposed a nonparametric test of PV versus CV. Their approach is entirely different from ours and is based on the variation in the number of bidders across auctions. They implement their test on a sample of US Forest Service (USFS) timber auctions and obtain mixed results. Haile, Hong and Shum's approach does not require a binding reserve price.[6] Recently, Hortaçsu and Kastl (2012) proposed a test of common values when some bidders have information about rivals' bids, and applied it to Canadian Treasury Bill auctions.[7] Their approach is tailored to the environment of Canadian Treasury Bill auctions and is also entirely different from ours.

Our paper also makes a few important econometric contributions by extending the Hill (1975) tail index estimator $\hat{\kappa}$ to imbalanced panels where bids are nonlinearly dependent within auctions of random size. There are only a few applications of tail index estimation for panel data: see, for example, Mikosch and de Vreis (2006) and Jongen et al. (2006). By exploiting theory developed in Hsing (1991) and Hill (2009, 2010), the estimator $\hat{\kappa}$ is shown to be asymptotically normal where the stochastic nature of bid counts is irrelevant. In particular, $\hat{\kappa}$ has the same asymptotic distribution as though bids were independent. Although this can simplify inference asymptotically, we show by the way of Monte Carlo simulations that for sample sizes that are realistic for auction applications, Hill (2010)'s asymptotic kernel variance estimator provides a better approximation of the small sample dispersion in $\hat{\kappa}$. We recommend using the kernel variance estimator.

We implement our test on a British Columbia Timber Sales [BCTS] dataset that contains all auctions conducted from January 14, 2004 to December 14, 2006. Timber auctions have attracted significant attention in the literature, while most of which focus on US data. The question of which model, PV or CV, is more appropriate for timber auctions has not been fully resolved.[8] Baldwin (1995) and Athey and Levin (2001) argue for the presence

[3] A more detailed discussion appears in Hendricks and Porter (2007).

[4] The distribution of bids near the reserve price satisfies a power-law, hence is regularly varying. This evidently marks a rare case of naturally occurring Paretian tails. In the statistics literature many Markov chains and stochastic recurrence equations are known to exhibit power-law tail decay, including nonlinear GARCH. Consult Embrechts et al. (1997), Gabaix (2008), Hill (2010, 2011b) for references.

[5] Krasnokutskaya (2011) has argued for the importance of accounting for the unobserved heterogeneity in the estimation of auction markups. See also the discussion in Paarsch and Hong (2006).

[6] In USFS auctions, the reserve price is typically nonbinding and the number of potential bidders is observable. See Baldwin et al. (1997), Haile (2001) and Haile and Tamer (2003).

[7] In Canadian Treasury bill auctions, bidders naturally fall into two groups—dealers and customers, and the former have an informational advantage over the latter.

[8] When we say CV, we mean a general model with interdependent values, not necessarily pure common values.