

Underwriting Government Debt Auctions: Auction Choice and Information Production¹

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Abstract

In this paper we examine a novel two-stage mechanism for selling government securities, wherein the dealers underwrite in the first stage the sale of securities, which are auctioned in stage 2, via either a Discriminatory Auction (DA) or a Uniform Price Auction (UPA). Using proprietary data on auctions during 2006-2013, we find that a) the first stage underwriting auction generate significant information, including predicting the likelihood of devolvement, and bid shading, and b) the outcome of the underwriting auction may generate enough asymmetry amongst bidders which may make DA dominate UPA in certain counterfactual situations. We document that the unique two stage auction design provides a market driven mechanism to simultaneously insure against auction failures, and produce information about the quality of the underlying issue.

1 Introduction

Auctions of government securities (or “Treasury”) are by far the largest class of auctions in the world, widely used across the globe to sell hundreds of billions of dollars worth of securities annually. Even in large and liquid markets, however, these auctions sometimes fail—for instance, the Chinese treasury auction on June 23, 2015, of Rmb26 billion attracted total bids of only Rmb25.16 billion, the second time this had happened within a year¹—and fear of auction failures has begun to haunt even the most developed markets.² McConnell and Seretto (2010) show that auction failures may impose ex-ante costs on issuers. In the context of Auction Rate Preferred Securities (ARPS) they show that investors demand a risk premium to account for potential failures. There is also evidence that the failure of ARPS market in 2008 led to significant losses of several mutual funds. Alongside fear of failure has been a persistent concern of possible collusion among bidders leading to subpar outcomes for the seller even when auctions do not fail.³

In this paper, we study a unique variant on standard Treasury auctions from India that addresses both of these concerns. Government securities are sold in India using a two-stage procedure. In the first stage, an underwriting auction is conducted, in which 100% of the

¹See “China treasury bond auction failure raises concerns on debt plan,” *Financial Times*, June 24, 2015; <http://www.ft.com/cms/s/0/00129228-1a3c-11e5a130-2e7db721f996.html#axzz4Dvegvzos>.

²In January 2016, a UK auction attracted barely enough bids to cover the amount on offer; the bid-to-cover ratio was the lowest since the last UK auction failure in 2009. (See, e.g., <http://www.bloomberg.com/news/articles/2016-01-26/u-k-flirts-with-failed-debt-auction-as-analysts-wince-at-depth>.) More recently, bond market volatility and Brexit-related issues have fed into fears of UK auction failures. See, e.g., <https://www.ft.com/content/02181264-dc92-11e5-827d-4dfbe0213e07> or <http://www.wsj.com/articles/u-k-government-bond-auction-could-fail-on-volatility-says-dmo-head-1433772690>. For concerns in the US auction markets, see <http://seekingalpha.com/article/3988056-failure-looks-like-10-year-treasury-auction-edition>.)

³A recent investor lawsuit in the US alleges, for example, that fully 69% of all treasury auctions appear to have “suspicious” outcomes based on the same analytical techniques that exposed the Libor fixing scandal. See <http://www.bloomberg.com/news/articles/2015-09-17/primary-dealers-rigged-treasury-auctions-investor-lawsuit-says>.

securities to be sold in the second stage auction are underwritten by the primary dealers. The mechanism is one in which the issuer obtains insurance against auction failure as well as unsatisfactory auction outcomes (which may be the result of collusive behavior or simply poor market conditions). The providers of this insurance are precisely the primary dealers in the main auction, and the insurance is obtained from them via a competitive *underwriting auction* which precedes the main auction. This concatenation of auctions generates a number of questions of economic interest including the impact of competitive underwriting, especially information production in the underwriting auction and its impact on main auction outcomes and behavior in the second stage main auction, as well as the costs and benefits of insurance; and a novel twist on an issue of traditional interest in auction theory: the differential impact of uniform-price versus discriminatory auction forms (UPAs vs DAs).⁴ Our analysis of these questions is facilitated by a proprietary dataset obtained from India’s central bank, the Reserve Bank of India (RBI).

A detailed description of the two-stage mechanism with an example is presented in the internet appendix, but here is a brief summary. In the first stage, the RBI, as debt manager, auctions the *underwriting* of the aggregate amount of the securities on offer. All primary dealers must mandatorily participate in the underwriting auction. This underwriting auction is discriminatory in style; its outcome determines the number of winning underwriters, the amount each winning entity underwrites, and the fees (“commission”) received for providing these underwriting services. Upon completion of the underwriting auction, the results are announced, and the second stage, the actual auction of the debt, commences. This second

⁴Government security auctions worldwide commonly use one of two structures. In a *discriminatory auction* (DA), winning bids are filled at the bid price; that is, the demands of the bidders are met by starting with the highest-price bidder down, until the entire quantity is exhausted. In a *uniform-price auction* (UPA), winning bidders pay a flat price, called the *stop-out price* for each unit they receive; the stop-out price is simply the lowest winning price, i.e., the maximum price at which the aggregate demand equals the supply being auctioned. A substantial literature has examined the theoretical implications and empirical performance of these auction forms, in particular, the possible dominance, from the seller’s viewpoint, of one auction over the other. We briefly review this literature in Section 2.

stage auction is either a DA or a UPA (the form is announced in advance of the underwriting auction), and participants in this stage include the primary dealers as well as other financial market participants. Outcomes in this second stage are determined in the usual fashion—but with an important caveat: the RBI may, at its discretion, ignore all or part of the second-stage submissions, exercise its insurance option, and “devolve” any or all of the auctioned quantity to the winning underwriters in the first stage.

The economics of this two-stage auction forms our focus in this paper. The framework that informs our analysis is straightforward. By obtaining insurance via the underwriting, the government gains an option, the right to “put” any part of the supply in Stage 2 back to bidders in the event of unsatisfactory second stage outcomes such as insufficient demand. (We note that over the period of our study, this right was exercised by the RBI in over 10% of the auctions.) Set against this benefit are the costs of obtaining this insurance. The direct costs are the underwriting commissions paid, the magnitude of which depends on bidding behavior in the underwriting auction, behavior that will in turn depend on a number of factors including the anticipated strength of demand in the second round and the possibility of devolvement and whether the main auction is a UPA or a DA. In addition, there may be indirect costs in the form of “bid shading” by participants in the main auction, the extent of which may depend on whether the bidder is also a winner in the underwriting auction, whether the main auction is a DA or a UPA and the nature of information revealed in the underwriting auction.

Motivated by these considerations, there are two broad sets of questions we investigate in this paper. First, we examine the differential impact on auction outcomes of the second stage auction being a DA versus a UPA; we are interested in both the impact this choice has on first stage underwriting auction behavior and outcomes, as well as the broader question of whether from the seller’s standpoint one auction form dominates the other. Second, we study the informational impact of the first-stage underwriting auction outcomes on second-stage behavior and outcomes. In particular, we wish to understand the extent to which first stage behavior and outcomes presage second-stage behavior and outcomes including the strength

of second-stage demand, the extent of bid shading in the second stage, the likelihood of devolvement following the second stage, and how second-stage bidding behavior is affected by being a “winner” in the underwriting auction. We also examine whether and to what degree “underpricing,” a widely-documented phenomenon in other Treasury auction markets, obtains here.

Theory and intuition offer some guide to what we might expect to find. Treasury auctions, like all common value auctions, are subject to a “winner’s curse” effect,⁵ which induces auction participants to “shade” their bids. An argument going back at least to Friedman (1963), and demonstrated formally in Milgrom and Weber (1982) in the context of single-unit auctions, notes that the winner’s curse stings less—and so participants in a common value auction are likely to bid more aggressively—under a UPA than a DA.⁶ However recent theoretical and empirical auction literature (Ausubel et al (2014), Jackson et al (2006), Hortacsu(2006)) have established that the discriminatory format may dominate the uniform price auction depending on bidder asymmetry and heterogeneity.

Jackson et al (2006) showed that discriminatory auction may generate higher revenue when the marginal valuations of bidders are farther apart. This points to a possible link between the pre-auction secondary market and the auction process and the optimal auction design. If the secondary market volatility is higher then it is reasonable to expect that the bidders have procured their inventory at very different prices. This makes the value of existing inventory quite different for different bidders thereby generating potentially very different marginal valuations for additional units. This in turn may affect the revenue of the bidders and auctioneer may be able to generate higher revenue by switching to discriminatory

⁵By definition the winning bids are the most optimistic of the submitted bids, This means the expected value of the object being sold conditional on everyone’s information is less than the expected value conditional on the information of only the winning bidder. This is the “winner’s curse.”

⁶Or, more accurately, under a second-price auction (the analog of UPAs in the single unit case) than under a first-price auction (the analog of DAs). The work of Wilson (1979), Back and Zender (1993) and others suggests a more nuanced set of possibilities obtains in multiple-unit auctions; see Section 2 for a review of the literature.

format when volatility is reasonably high in the secondary market.

The volatility of the secondary market should potentially also affect the cost of insuring auctions that may get devolved. This is a channel through which secondary market volatility may affect the underwriting commission. Suppose that the bidders' cost of insuring is heterogeneous due to differential costs of procuring and holding inventory. This can result in a volatile demand for underwriting premia. If the underwriters expect that the underwriting bid functions of their rivals are more volatile then, *ceteris paribus*, the probability of winning any underwriting amount is higher with bidders submitting a higher underwriting commission. This in equilibrium will potentially make the equilibrium underwriting commission cut-off rates higher in a discriminatory auction. To the extent that the underwriting commission is also a signal about the quality of the underlying issue, higher underwriting commissions should prompt bidders to shade their bids more in a discriminatory format. If all the other bidders are shading their bids more, *ceteris paribus*, the primary dealers should also shade their bids more in equilibrium in DA relative to UPA.

The above arguments suggest that a first-stage underwriting auction outcome commission rates should be informative about the second stage auction outcomes. Specifically, a higher first stage commission rates should, *ceteris paribus*, be associated with discriminatory auctions, weaker second stage demand, greater bid-shading and a higher probability of devolvement. This has significant policy implications, as we document in this paper, the unique two stage auction method can provide a market driven mechanism to simultaneously insure against auction failures, and produce information about the quality of the underlying issue.

Summary of Results

Using a proprietary data set obtained from the RBI that covers 590 reissue auctions of government securities in India from 2006-2013, we find empirical confirmation of the economic intuition developed in the earlier section. During this period the debt manager switched the

auction format five times (thrice in 2009, once in 2012 and once in 2013) from uniform to discriminatory or vice versa. Underwriting commissions for DAs are significantly (about *two* times) higher on average and exhibit more volatility than those for UPAs. Award concentrations in the first stage are also higher for DAs. So, importantly, are the second-stage bid shading and consequent main auction underpricing.⁷ (It is important to emphasize that the duration risk of the securities auctioned did not differ across the two auction formats in our sample.)

The greater bid-shading that we find under DAs suggests that perhaps the benefits of obtaining underwriting insurance (the ability to “put” the securities to winning underwriters) may be greater for DAs than UPAs. We estimate a monetary measure of the benefits in each devolved auction by comparing the revenues obtained by the government under devolvement to what it would have obtained without devolvement. We find that the average benefits per auction are almost two times higher under DAs than under UPAs. However, this is insufficient to offset the higher underwriting costs under DAs, which are, as we noted, on average more than *two* times higher than under UPAs. As a consequence, while the average *net* benefit per UPA is INR 5.9 million, there is a small net *loss* of INR 1 million on average for DAs.

Turning to the impact of the first stage underwriting auction on the second stage behavior and outcomes, we find strong evidence that underwriting auction outcomes predict the nature of the second-stage selling outcomes, such as devolvements, bid-shading and underpricing. We find that the bid shading by primary dealers in the main auction is, *ceteris paribus*, larger the more “pessimistic” are underwriting auction outcomes (especially, a higher underwriting auction cut-off price); individual bidder level bid shading is also greater the larger the amount underwritten in the first round by the respective bidder, and is larger under DAs than UPAs. These results are obtained after controlling for information in pre-auction secondary market prices, which are trumped by information revealed in the underwriting auction. They are

⁷These results on award concentrations are similar to the evidence presented in Malvey, et al (1992) which was one of the reasons cited for the U.S. Treasury’s decision to switch from DAs to UPAs.

also economically significant; for example, one standard deviation increase in the amount underwritten increases bid shading by about 1.4%.

Measures of information produced in the first stage auction are also statistically and economically significant in explaining the strength of demand and the probability of devolvement in the second stage auction. In particular, measures of aggressiveness of the underwriting bids (such as the stop-out yields) and bidder uncertainty in the first stage auction matter. Higher underwriting stop-out yield and higher bidder uncertainty predict higher probability of devolvement. Auction-related variables trump measures constructed from secondary market information such as volume of trading prior to bidding in explaining the outcomes in stage 2 auctions.

Finally, a long literature in Treasury auctions has found evidence of “underpricing” in the auction (relative to market prices), a phenomenon commonly attributed to bid-shading caused by winner’s curse fears. Consistent with this literature, we too find evidence of underpricing in the main auction: on the auction day, the closing secondary market prices are higher than the auction-determined price. In addition, we also find evidence of price pressure in pre and post-auction dates. Pre-auction prices are systematically higher than the equilibrium prices at which the second stage auctions clear the supply, as are the post-auction prices. This leads to a “V” shape reminiscent of the results in the auctions concessions literature, as in Lou, Yan and Zhang (2013). Lou et al attribute the price pressure phenomenon to primary dealers’ limited risk bearing capacity and end-investors’ imperfect capital mobility. The two-stage nature of the Indian treasury auctions, where the first stage underwriting auction acts as an insurance mechanism against devolvement of the second stage auction, is a setting where the primary dealers’ risk bearing capacity should perhaps play an even more important role. We find that the shoulders of the “V” shape are explained by the information produced in the first stage auction, and they improve the explanatory power well beyond other measures which rely only on secondary markets data.

One issue that has plagued the analysis of the treasury auction literature also applies to our setting: are there unobserved factors that prompt the debt manager to choose one

auction mechanism over another? This unobserved heterogeneity, if present, may affect our reduced form results described above by creating an endogeneity bias. What factors might affect the auctioneer's auction format choice is an open question. Brenner (2009) noted that "Most countries use a discriminatory format (24) while 9 countries use a uniform auction. It has been argued in the literature, both theoretically and empirically, (Jackson et al (2006), Hortacsu (2012)), that which format dominates in terms of revenue is an empirical question. Jackson et al (2006) outlined a scenario when discriminatory format dominates the uniform price format. They argued that if there is a big difference in the marginal valuation of the bidders, DP format may generate higher revenue than the UPA format.

One of the factors that may affect the marginal valuation of the bidders is the acquisition and off-loading costs of their inventory in the pre and post auction secondary market. The primary dealers also play the role of market makers in the secondary market and their behavior in the main auction may be influenced by the pre and post auction secondary market. Hence the auctioneer may take a cue from the pre-auction secondary market about the possible dominance of auction format and set the format accordingly. The role of the pre-auction secondary market information as a determinant of auction type choice and bidding behavior however has not been analyzed in the literature. Brenner et al (2009) pointed this out as a future research topic: "The effect of the secondary market on auction design is an interesting topic and so is a study about the switch that some countries have made, from one auction type to another, the reasons behind it and the consequences of it".

The presence of such variables which may affect the auction format choice leads to endogeneity concern. Although we have controlled for various pre-auction secondary market variables throughout, it does not rule out the possible unobserved heterogeneity bias. In section 5 we therefore use a switching regression technique to address this issue. Our results are robust to controlling such unobserved heterogeneity. Using switching regression technique we can also do the counterfactual analysis for our main variables: what would have been the probability of devolvement, bid-shading etc. if the auctioneer chose a different format. Consistent with the predictions of Ausubel (2014) and Jackson et al (2006) we found that

UPA does not always dominate the auction choice format.

The rest of this paper is organized as follows. Section 2 reviews the literature. Section 3 describes the data, defines the variables of interest in our analysis, and provides summary statistics. Section 4 presents our results, Section 5 presents robustness and counterfactual analysis, Section 6 concludes.

2 Related Literature

Two Stage Auction

Theoretical analysis of the information production role of a first stage auction in a two-stage setting has so far been confined to the single unit setting in the literature. Ye (2007) in a single unit auction setting, showed that if the first stage bidding has payoff relevance for the bidders, then bidders will bid truthfully in the first stage indicative bidding. We are not aware of any theoretical analysis of two-stage auction in a multi unit setting. To our knowledge, we are the first to provide an empirical analysis of multi-unit auctions in a two stage setting. In our case, the first stage bidding has two sources of payoff relevance.

a) The commission rate that bidders should be charging to underwrite and insure. Bidders payoff comes from direct commission as well as net of any costs in case of possible devolvment. The commission rate should reflect the fair premium they should be charging. This creates direct payoff relevance. Given that there may be some common value element before the first stage, truthful revelation by one in equilibrium prompts other to reveal truthfully.

b) The additional source of payoff relevance comes from the implications of reduction of winners' curse in the second stage based on truthful revelation of first stage signals by all PDs. If the first stage auction generates enough information for the possibility of devolvment and valuation of the underlying issue then it reduces the winners curse for all the primary dealers in the second stage. This may induce truth telling as a best response if others are telling the

truth.

A simple example may be useful here to illustrate this point. Suppose there are two primary dealers and both of them have the perfect information about the issue quality. The issue could be either good or bad. If the quality of the issue is bad then it ends up devolving in the second stage and the underwriter who had underwritten the first stage auction has to take the issue at a loss in its book. In this simple setting it is easy to see that truth telling is a best response. For example, suppose the issue is of bad quality. Then if underwriter 1 tells the truth and calls it bad (and charges a high commission) then it is the best response for underwriter 2 to call it bad as well. If underwriter 2 deviates and calls it good (and charges a lower premium) then he ends up winning the underwriting rights for an issues which will devolve post the second stage and hence loose.

The discussions above guide us to the following hypothesis related to the two-stage auction format and the information production role of the first stage.

H1: The first stage underwriting auction outcome predicts devolvement, aggregate demand, bid shading in the second stage.

Uniform Price vs. Discriminatory Price

The literature on auction theory and empirical work in Treasury auctions is extensive. A question of particular interest in this literature has been whether uniform-price auctions (UPAs) dominate discriminatory auctions (DAs) from the seller's perspective. For auctions of a single indivisible unit, Milgrom and Weber (1982) and others have shown that second-price sealed bid auctions (the analog of UPAs) strictly dominate first-price sealed bid auctions. A fundamental reason is the impact the auction form has on the winner's curse. In unit auctions, winning implies that the conditional value of the good upon winning will be updated to a lower value relative to unconditional expectation. Rational bidders take this winner's curse into account and shade their bids. The extent of bid shading will depend on the precision of the signals that they have about the good that is being auctioned, but *ceteris*

paribus will be lower for second-price auctions than for first-price auctions, as intuition suggests. Based on this intuition, a long line of authors from Friedman (1963) to Chari and Webber (1992) has made the argument that UPAs will generate more revenue for the seller than UPAs. However, theoretical support for this position is mixed: Treasury auctions are divisible good auctions, and the work of Wilson (1979) and Back and Zender (1992) suggests that a more nuanced set of outcome possibilities than in unit auctions.⁸ More recently, however, Goldreich (2007) has offered a set of conditions under which UPAs do dominate DAs. Ausubel (2014), Jackson et al (2006) have shown that whether the UPA dominates the DA is an empirical question and depend on bidder heterogeneity and asymmetry.

A substantial empirical literature has also explored the implications of auction theories in the context of Government securities auctions. Related work includes Boyarchenko et al (2015), Hortascu and Kastl (2012), Hortascu and McAdams (2012), Keloharju, Nyborg, Rydqvist (2005), Nyborg and Sundaresan (1996), and Nyborg, Rydqvist and Sundaresan (2002), among others. The work of Lou et al (2014) and Fleming et al (2016) document the evidence of price pressure, referred to as the decline of the underlying security prices in secondary market for the period leading up to the auction and increase afterwards.

Recent work by Hortacsu and McAdams (2012) suggests that a switch from Discriminatory to Uniform price auctions may not produce significant gains to the seller. The role of the secondary market and its impact on auction format choice has not been explored in the literature and referred as a future research topic in Brenner (2009).

The extant multi-unit auction literature as outlined above describes various equilibrium arguments about why an uniform price (UPA) format may dominate the discriminatory price format (DA). In a two-stage auction format where the second stage can be either UPA or DA; if we take one such equilibrium in the second stage, then via backwards induction, we need to explain about what kind of behavior we should expect in equilibrium in the first stage

⁸In such auctions, Ausubel (1997) has identified the problem of “champion’s plague”: the more the bidder wins in auction, the worse off the bidder is. A rational bidder in a multi-unit auction will reflect these economics by lowering the demand curve.

underwriting auction. If we start from a second stage equilibrium where UPA dominates the DA in terms of bid-shading then there will be more bid-shading in equilibrium in the second stage. This will in turn make the ex-ante devolvement more likely for DA. If ex-ante devolvement is more likely in the second stage then the primary dealers in the first stage should demand higher premium to underwrite and insure the underlying issue. This in equilibrium should lead to higher underwriting commission for DA relative to UPA.

The above discussion guide us to testable hypotheses as described below for the relative performance of UPA vs DA in a two stage setting.

H2: (UPA vs. DA in first stage) Underwriting premium outcome in the first stage underwriting auction will be higher on average if the second stage is DA format relative to UPA.

H3: (UPA vs. DA in second stage) : Bid-shading and auction underpricing will be higher and bid cover will be lower in DA relative to UPA.

An Example

In this section we give a hypothetical example of the auction mechanism via discriminatory auction for the re-issue of a 10-year bond issued. This is a re-issue, and hence the auction was conducted on a price basis.

As described in detail in the internet appendix, the underwriting part of the auction has two components. First, all primary dealers are subject to a mandatory *minimum underwriting commitment* or MUC. The commitment amount is the same across all dealers, irrespective of differences in their capital or balance sheet size⁹. The second component is the auction part. All primary dealers are required to submit bids for *additional competitive underwriting* or ACUs for the remaining 50%

⁹See, Revised Scheme for Underwriting Commitment and Liquidity Support, RBI document, Money, Banking and Finance, Volume 77, May 2006. Most of the institutional details are derived from RBI publications. See also Sahana and Ghose (2012).

In the underwriting stage, the aggregate MUC amount was half of the issue amount and the ACU underwriting auction for the remaining half of the issue amount. A total of 19 primary dealers participated in the auction, same as the number of dealers in most part of the data. In this hypothetical auction the ACU underwriting auction has a total 49 bids (quantity-commission rate pairs) submitted, representing a total quantity of far above the issue amount, and well above the amount to be underwritten. The lowest commission rate submitted was 1.8 (per INR 100 face value of bonds) for a quantity of INR 200 million, while the highest submitted commission rate was over 50 times higher at 100 per INR 100 face value. The bids included one for a quantity of INR 14 billion (28% of the entire notified amount) by a single bidder at a rate, which also became be the cut-off commission rate. The aggregate underwriting supply curve is pictured in the upper panel of Figure 1; the large flat segment around the cut-off represents the INR 14 billion submission; INR 13.50 billion of this bid was met, representing 27% of the entire notified amount of the auction. Note the sharp steepening of the curve a bit further down. The weighted-average commission rate of all successful bids—which was the commission rate for the MUC for those dealers who underwrote at least 4% of the notified amount in the ACU underwriting auction—was roughly INR 0.000033 per INR 100 face value, while the weighted average commission rate of the three lowest bids—used as the MUC commission rate for all other dealers—worked out to only 60% of this amount at INR 0.000020 per INR 100 face value.

In the main auction, total bids well in excess of the issue amount on offer—were received, ranging from a high bid of INR 100.15 for a quantity of INR 100 million to a low bid of INR 97 for a quantity of INR 1 billion. (Bids are for INR 100 in face value.) The aggregate demand curve is pictured in the lower panel of Figure 1; as in the underwriting auction, the aggregate curve (here, a demand curve) steepens sharply beyond a point. The cut-off was reached at a price closer to INR 99.5.

3 The Data and Summary Statistics

This section describes the data set, defines the variables of interest in our analysis and presents summary statistics.

3.1 Data

Our data set has two components: primary market auction data and secondary market trading data. The secondary market data were obtained from the secondary market trading data repository: Clearing Corporation of India Ltd. (CCIL). The primary market data were received from the Centre for Advanced Financial Research and Learning (CAFRAL), a research wing of the RBI. The primary market dataset has two components, the first stage underwriting auction that determines underwriting commissions and quantities, and the associated second stage main auction for the government securities. For each auction, We have all the basic information such as auction date, notified amount of the government bond being auctioned, its maturity date and coupon rate, the number of primary dealers participating, individual price quantity pair bids by each bidders in the underwriting as well as in the main auction.

The identities of the primary dealers and other bidders are masked, but in a consistent way across auctions, that enables us to follow the bidding behavior of each primary dealer across the first stage (underwriting) auction and the second stage (bond) auction for the same issue. Our total database covers 678 auctions of government securities over the period 2006- 2013. The secondary market data contains intra-day trading information (prices and quantities) for each trade for each bond. We have secondary market trading price and volume information for the bonds in 590 of the 678 auctions.

We observe the complete supply curve (commission rate-quantity pairs) submitted by each dealer in the ACU auction, and thereby, the cut-off commission rate at which the entire auctioned quantity is underwritten, as well as the commissions received by each primary

dealer as ACU commission and MUC commission. The availability of this data enables us to compute an important component of the costs of underwriting the sale of government securities.

The second stage auction may be, also as noted in the internet appendix on the institutional design, uniform-price or discriminatory in style. Of the 590 auctions in our dataset, 415 were of the uniform price format and 175 were discriminatory. During our sample period (2006-2013), the debt manager switched the auction format five times (thrice in 2009, once in 2012 and once in 2013) from uniform to discriminatory or vice versa. For each auction, we observe the entire demand curve (price-quantity pairs) submitted by each bidder, and the cut-off auction price, the highest price at which demand equals or exceeds supply. A total of 73 of these auctions ended up being devolved by the RBI. For the devolved auctions, we also observe the devolvement price set by the RBI and the quantity devolved to each primary dealer. For each devolved auction, we also calculate the price at which the auction would have cleared the entire supply had devolvement not occurred. (Since each of the primary dealers is required, in the main auction, to bid for an amount at least equal to the amount underwritten by them, the total demand always equals at least 100% of the notified amount (i.e., the amount being auctioned), so this hypothetical clearing price is always well-defined.)

3.2 Devolvement by the RBI

The bonds being auctioned in the second stage may be devolved at the RBI's discretion. By design of the underwriting auction the underlying issue is 100% insured; i.e. primary dealers would have underwritten the entire issue in the first stage in exchange of the Minimum Compulsory Underwriting (MUC: 50% of the notified amount) and Additional Competitive Underwriting (ACU: remaining 50% of the notified amount) commissions. The primary dealers are required to bid at least their entire underwriting commitment in the second stage main auction. Hence, by design the second stage will receive bids equal to at least 100% of the issue size and bid-cover ratio can never be less than one. Hence no auction can devolve

due to lack of demand. Auctions devolve if the RBI believes that the auction-identified price is not satisfactory. However, there is no pre-announced devolvement policy by the RBI, making it somewhat akin to choosing a secret reserve price in the second stage auction.¹⁰

In case of a devolvement, the RBI announces (i) a price for the underlying issue, which is higher than the auction identified cut-off price, and (ii) a devolved amount which is then absorbed pro-rata by the primary dealers on the basis on their underwriting commitments. For example, suppose based on the actual demand curve submitted by all the bidders, the auction-identified cut-off price (where the aggregate demand equals the notified amount) is INR 97.83 for a INR 100 face value bond. However, suppose the RBI finds that this price is too low and decides to choose a cut-off price of INR 98.50. Suppose further that based on the actual demand curve, a cut-off price of INR 98.50 leads to a shortfall of INR 400 million. In this case, the RBI would publicly announce¹¹ that the auction is being devolved at a cut-off price of INR 98.50 and the shortfall of INR 400 million is then devolved pro-rate to the primary dealers based on their underwriting commitments. The primary dealers may offset their accepted bids (bids above price INR 98.50 in the example) against their underwriting commitment. For example, if primary dealer 1 has an underwriting commitment of INR 100 million of the devolved amount of INR 400 million, and based on his submitted bids in the second stage auction if INR 70 million are above price INR 98.5, then he has to take INR 30 million of the devolved amount on his book at the price of INR 98.50.¹²

Out of 73 total devolvments in our data, a large number of devolvments (21) happened in 2009 at the height of the financial crisis, while another 24 took place in 2013. The remaining devolvments were spread out over 2008 (2), 2010 (4), 2011 (12) and 2012 (4).

¹⁰RBI may also cancel an auction altogether, see for example the RBI notification on auction announcement:<https://rbi.org.in/scripts/NotificationUser.aspx?Id=4555&Mode=0>. Given very small sample size (less than 10) of cancelled auctions, we believe that cancelled auctions will not substantially affect our results. We therefore exclude cancelled auctions.

¹¹For an example of such an announcement, see <http://www.thehindubusinessline.com/todays-paper/tp-money-banking/gsec-auctionrs4000crdevolvesonprimarydealers/article2538466.ece>

¹²See the RBI notification: <https://www.rbi.org.in/scripts/NotificationUser.aspx?Id=5820&Mode=0>

Devolved and successful auctions did not differ much in terms of the issue characteristics of the auctioned securities as the following table shows. The differences in duration or issue size are not statistically significant either by t -test or by the Kolmogorov-Smirnov test of equality of distribution.

	Successful	Devolved	Difference
Duration	11.69	11.41	0.28
Notified Amt (INR billions)	38.74	38.19	-0.42

The next table describes summary statistics of the devolved auctions compared to successful auctions. The average devolved amount is about 21% of the issue size as shown in Panel A with significantly higher devolvement happening in discriminatory auctions. To get a feel for how the RBI may be setting the devolvement price, we compare, in Panel B, the price difference between the devolved price set by the RBI and the counterfactual price that would have prevailed had RBI not devolved the issue, normalized by the pre-auction secondary market price for the same bond. On average, the devolvement price was set about 0.39% higher than the counterfactual price relative to the pre-auction secondary market price (e.g., if the pre-auction secondary market price were INR 100, then the devolved price is INR 99.61), but there is a significant difference between uniform and discriminatory auctions with the latter commanding larger discounts on average. The table below describes the percentage of notified amount devolved.

	Uniform	Discriminatory	Difference
Mean	20.9%	23.9%	-3.0%
Median	19.8%	22.3%	-2.5%

The table below describes the difference between the counterfactual price that would have prevailed had RBI not devolved and the devolved price set by RBI.

	Uniform	Discriminatory	Difference
Mean	0.36%	0.56%	-0.20%
Median	0.27%	0.24%	0.03%

Based on the data, it does not clearly appear that the RBI follows a threshold policy based on this discount to decide on devolvement. The maximum discount given in some successful auctions (3.38%) is much higher than the maximum discount allowed in some devolved auction (2.1%). If the RBI was following a threshold policy based on the discount relative to the secondary market price then those should have been devolved. Therefore based on the summary statistics in these tables, it appears that the RBI follows a secret reserve price policy, which is difficult to forecast based on pre-auction behavior and issue characteristics. In section 5, we analyze the determinants of devolvement in a regression setting.

We also note another interesting feature in the devolved auctions. The uniform price auction seems to dominate the discriminatory price format in terms of the amount of discount. This is consistent with our narrative given in section 2. If the equilibrium bid shading is higher in discriminatory auction then auction identified price is likely to be lower in discriminatory format which increases the ex ante probability of devolvement for DP auctions. This should lead to higher discount based on the auction identified cut-off price in the DP format, which actually devolved ex-post as seen in panel C of table 2.

3.3 Summary Statistics & Non-parametric Results

Tables 1 provide some basic summary statistics across the auctions in our data set. They highlight some important points. Devolvement is more common when the main auction is UPA than a DA; 17 out of 175 (or roughly 10.2%) of DAs were devolved compared to 56 out of 511 (about 11%) of UPAs. And strikingly, when the second-stage auction is a DA, the average underwriting commission cut-off in the first stage is, at 6 basis points, more than *two times* higher than the corresponding number when the second-stage auction is a UPA.

Figure 1 in the appendix provides kernel densities for selected Stage 1 and Stage 2 outcomes. The figure makes several points. The top left panel shows that the underwriting allocations in stage 1 are much more concentrated when Stage 2 auctions are DAs compared

to when they are UPAs. The top right panel shows that the average underwriting cut-off rates are much more skewed to the right when the Stage 2 format is a DA; the underwriting cut-off rates are also much higher when the Stage 2 auction format is a DA. These findings are consistent with the intuition expressed in the Introduction and hypothesis 2 and 3 that, anticipating higher bid-shading under discriminatory auctions (and thence a greater probability of devolvement), primary dealers will demand higher underwriting premium if the second stage is a DA. Primary dealers are also asymmetric in terms of their inventory holding capacity in case of a devolvement; for example, Bank PDs can absorb some of their inventory towards reserve requirements. In turn, this may lead to the wider variability of underwriting bids documented in the appendix table 1, and to concentrated underwriting allocation as in the top left panel.

That Stage 2 bid-shading is significantly higher when the auction format is a DA is confirmed in the lower left panel of Figure 1 in the appendix. The lower right panel looks at devolved auctions and the difference between the actual price (at which devolvement occurred) and the counterfactual price (that would have prevailed had devolvement not taken place). As anticipated, this difference is much larger for DAs. Overall Figure 1 in the appendix supports the hypothesis that the DA format not only makes the second stage less competitive but has a significant effect on the level of competition of the first stage too.

Table 2 in the internet appendix provides the names of the primary dealers (PDs) who were active in mid-2014. (There are 20 PDs during this period; through much of the period of our study, the number of primary dealers was a bit smaller at around 16-18.) The PDs are classified as either standalone primary dealer (Standalone PD) or bank primary dealer (Bank PD). Bank PDs are those primary dealers who also provide other banking services in India. Our masked identities include information on whether a primary dealer is a Bank PD or a Standalone PD. The distinction is important because Bank PDs may use the amount of government bonds won in an auction towards meeting their “statutory liquidity ratio” or SLR, the reserve requirement that commercial banks in India are required to maintain with the RBI. The ability to buy in the auction to fulfill the SLR may induce the Bank PDs to

bid differently from the Standalone PDs. We explore this possibility later in our analysis.

Key Economic Variables of Interest

Table 2 describes the key economic variables of interest that we use as dependent variables in our various regressions. There are four key ones: a devolvement dummy, the bid-cover ratio, the degree of bid shading by an individual dealer, and the degree of auction underpricing. Section 4.1 uses a logistic regression with a devolvement dummy to estimate the probability of devolvement. Section 4.2 examines bid-shading at the dealer level defined as

$$1 - \frac{\text{value-weighted average bid}}{P_{PostAuc}},$$

where “value-weighted average bid” is computed from the bids submitted by that dealer in that auction and $P_{PostAuc}$ is the post-auction secondary market price measured after the auction results were announced on auction day. (That is, a lower submitted value-weighted average bid relative to the post-auction secondary market price corresponds to a greater degree of bid shading.) Finally, Section 4.3 looks at the degree of price pressure in the main auction, defined as

$$\ln \left(\frac{P_{t+1}}{\text{Auction Stop-out Price}} \right).$$

Table 3 provides summary statistics on these variables. On average, there is bid shading of about 0.54 basis points and price-pressure of about 0.2 basis points per INR 100 in face value. But the data reveals wide variability across auction formats. Discriminatory auctions result in a substantially greater degree of bid-shading and price pressure relative to uniform-price auctions. Similarly and unsurprisingly, auctions that were ex-post devolved were associated with a much greater degree of bid-shading and price pressure relative to those that turned out successful.

Independent Variables

Table 4 defines the right-hand side variables we use in our regressions, listed alphabetically.¹³ The variables fall into three groups.

The first group consists of numbers that characterize the underwriting auction: the underwriting cut-off price, and amount “won” by each dealer (i.e., the amount underwritten in the ACU auction).

The second group comprises outcomes of the main auction: such as the notified amount (the amount being auctioned), the time-to-maturity of the bond being auctioned, and the number of bidders participating in the main auction.

The final group of variables is data from secondary markets (both pre- and post-auction). Since the underwriting auction is held the day before the main auction, for pre-auction data, we use data from two days before the main auction. The secondary market data used in our analysis includes the pre- and post-auction market prices (defined as the value-weighted price obtained from all trades on that day), the volume of trading (measured in INR billions), the number of trades and the standard deviation of intra-day pre-auction prices (calculated using all trades on that day). The last variable is a proxy for the winner’s curse effect; a larger standard deviation implies a larger range of opinions concerning the correct market price.

Table 3 in the internet appendix provides summary statistics on each of these variables.

4 Regression Analysis

As we noted in the Introduction, our main expectations, based on the extant theoretical literature, are twofold. First, we expect first stage-underwriting auction outcomes to be informative about key outcomes in the second stage main auction, in particular, concerning the likelihood of devolvement, strength of main auction demand, and second-stage bid shading

¹³We also examined the impact of several other variables but found that they were insignificant and did not affect the results in any way, so in the interest of brevity, we do not describe them here.

and auction underpricing. Second, we anticipate that when the second stage is a DA, rather than a UPA, bidding will be less aggressive, there will be more bid shading and greater auction underpricing, and involve higher underwriting commission rates. The descriptive statistics in the last section and the kernel density plots provided some evidence of the last set of hypotheses. We build on that evidence here using regression analysis.

Sections 4.1 look at the probability of devolvement and establish the key role of the underwriting auction in information production. Potential bid-shading at the dealer level is the subject of Section 4.2, while Section 4.3 looks at bid cover in the main auction. Finally, Section 4.4 looks at the overall economics of the auction, to compare the outcomes under DAs and UPAs.

4.1 The Likelihood of Devolvement

A key question underpinning our analysis is the the information content of the underwriting auction: Does the underwriting auction generate information in addition to that already reflected in pre-auction secondary market prices?

Table 5 provides a first answer. The table examines the extent to which the likelihood of devolvement is predicted by outcomes of the underwriting auction. It presents the results of a logistic regression where the dependent variable takes the value 1 if the auction devolved and 0 if was successful (i.e., did not devolve). The independent variables include both pre-auction secondary market variables (the variance of pre-auction market prices and the volume of pre-auction trading) and underwriting auction outcomes (including the variability of ACU bids and the underwriting cut off price), as well as time dummies. Since there was no devolvement in the year 2007, we lose those observations due to the presence of year fixed effect and 501 observations for the final set of regressions.

As the fourth (and most inclusive) column of the table shows, the only pre-auction or underwriting auction variable that is statistically significant in explaining devolvement is the underwriting cut-off price, and in the expected direction: a higher value of the cut-off

increases the probability of devolvement. Other underwriting auction outcome variables lose significance when the underwriting cut-off is included, while the pre-auction information is (as Column 1 shows) even by itself of limited value in explaining devolvement.

The underwriting cut-off price is also economically significant. One percentage point increase in the log underwriting cut-off increases the probability of devolvement by about 5.1%.

4.2 Bid Shading in the Main Auction

As auction theory has noted, participants may rationally “shade” their bids in common value auctions in response to the threat of a winner’s curse; bid shading may also stem from other sources such as risk-aversion.

Table 3 shows that there is average bid-shading over all dealers and all auctions of around 0.54 basis points (i.e., INR 0.0054 per INR 100) in our data. The average degree of bid shading is substantially higher in discriminatory auctions than in uniform-price auctions (0.74 bps versus 0.43 basis points) and in devolved auctions than in successful ones (1.06 bps versus 0.5 basis points).

Table 6 examines the determinants of the degree of bid-shading at the level of the primary dealer. The dependent variable in the regressions is the degree of bid-shading by a dealer; the independent variables include, apart from the ones identified in Table 4, a dummy variable indicating if the bidder is a Bank Primary Dealer (as opposed to a standalone Primary Dealer); as we noted earlier, Bank PDs can use the amount won in the auction towards their statutory liquidity requirements.

Column 4 of the table, the most inclusive one, confirms the key role of the underwriting auction in influencing dealer behavior in the main auction. As the numbers show, the degree of bid shading increases with an increase in the underwriting cut-off and with an increase in the standard deviation of pre-auction secondary market prices, a proxy for the winner’s curse.

A key variable of interest is the impact of auction format on bid-shading. As we argued earlier that in equilibrium the primary dealers shade their bid more in the discriminatory format which in turn led them to demand more underwriting commission in the first stage. This channel is confirmed here, the uniform auction dummy is significantly negative, signifying that primary dealers shade their bid less in uniform price auction relative to discriminatory format.

The coefficients are also economically significant. A one standard deviation increase in the log of the underwriting cut-off increases the degree of bid shading by .14 basis points, while a similar increase in the standard deviation of secondary market prices increases the degree of bid shading by .18 basis points. A move from discriminatory to uniform price format reduces the bid shading by about 0.8 basis point.

Besides these, a number of other variables are also significant in explaining bid shading. For instance, bid shading increases with the time-to-maturity of the bond being auctioned (larger duration risk), while a higher volume of pre-auction secondary market trading (greater secondary market liquidity) decreases bid shading. Bid shading also decreases if the dealer is a Bank PD and increases with the amount won in the ACU auction.

4.3 Price Pressure and Bid Cover in the Main Auction

One potential consequence of bid shading by dealers is underpricing in the main auction (relative to the secondary market price). Table 3 provided summary statistics on bid-cover and price pressure in our data set¹⁴ The average level of price across all auctions is around 0.21 basis points (i.e., INR 0.0021 per INR 100 face value), and is substantially higher in discriminatory auctions than in uniform price auctions (0.32 bps versus 0.16 basis points). Unsurprisingly, the degree of price pressure is also sharply higher in auctions that end up being devolved versus ones that do not (0.61 basis points versus 0.16 basis points). Similarly,

¹⁴The results are qualitatively similar if, for discriminatory auctions, we use the weighted average of winning bids in the denominator, rather than the auction stop-out price.

auction demand (bid-cover) is much lower for devolved auction relative to successful auctions (1.8 versus 2.39).

Figure 2 compares the average auction-identified price to the averages of both pre- and post-auction secondary market prices (computed two days before and two days after the auction, respectively). The bands represent the mean 95% confidence intervals for each of these quantities. In all the formats of the auctions, the prices depict a V-shaped pattern signifying underpricing in the auction relative to both pre- and post-auction secondary market prices. Expressed in rupee terms, the total volume of ex post price pressure is INR 49.31 billion (21 basis points of the total notified amount of INR 23,482 billion).

Table 7 looks to identify the determinants of price pressure and auction demand using both pre-auction and underwriting auction variables on the right-hand side. As in the earlier analyses, the underwriting auction cut-off again emerges as a significant explanatory variable. It is also economically significant. Using the coefficients in the last column and against an average level of price pressure in our data of 0.21 basis points, a one standard deviation increase in the underwriting cut-off increases price-pressure by 0.15 basis points.

In addition, as with bid shading, the volume of trading in the secondary market (a measure of market liquidity) again emerge as significant drivers of underpricing with the degree of price-pressure decreasing with an increase in secondary market liquidity. The winner's curse proxies however are insignificant.

Hence the regressions results supports our hypotheses 1, 2 and 3. Specifically, the underwriting auction predicts devolvement, bid shading, aggregate demand and price-pressure. Moreover the UPA format dominates the DA format with lower bid shading, auction price-pressure and higher bid cover. We shall later see in section 5 that in counterfactual analysis the ranking of UPA versus DA is not clear.

4.4 The Economics of the Underwriting Auction

Tables 4 and 5 in the internet appendix summarize the direct cost and direct realized benefit of the underwriting auction from the RBI's standpoint. In option-theoretic terms, the cost is the premium paid for the option to put the bonds to the dealers and the benefit is the depth-in-the-money of the put when it is exercised.

The direct cost is the total amounts paid as underwriting commission (for both the MUC and the ACU) summed over all the auctions in our data. Table 5 in the internet appendix shows that the mean direct costs when the second stage auction is a DA is, at INR 54 million, roughly 6 times the mean direct cost of INR 9 million when it is a UPA.

The direct realized benefit is the extra revenue generated from devolvement, i.e., it is the sum over all devolved auctions of the amount

$$(P_{\text{dev}} - P_{\text{auc}}) \times \text{Devolved Amount} \div 100,$$

where P_{dev} is the price (per INR 100 in face value) at which the devolved amount is devolved and P_{auc} is the auction stop-out price (per INR 100 in face value) that would have prevailed in the absence of the devolvement. Table 6 in the internet appendix shows that the direct realized benefit of underwriting when the second stage is a DA is around INR 13.4 million, about three times the direct realized benefit when the second stage is a UPA.

The final column of Table 6 in the internet appendix describes the direct *net* benefits of the underwriting auction, i.e., the direct realized benefits minus the direct costs. While the underwriting auction provides, on average, a small net benefit to the RBI of INR 2.1 million per auction, the net benefit under UPAs is about INR +4.8 million while that under DAs is negative at INR -1 million.

5 Robustness: Endogeneity of Auction Choice

In this section we allow for the endogeneity of the auction format choice by the debt manager (RBI) and the role of other macro factors affecting the choice. Both theoretical and empirical auction literature (Ausubel et al (2014), Jackson et al (2006), Hortacsu(2006)) have established that the notion that the uniform format dominates discriminatory in terms of revenue is an old and incorrect idea. The role of the pre auction secondary market information and other macro factors as a determinant of auction type choice and bidding behavior however has not been analyzed in the literature. Brenner et al (2009) pointed this out as a future research topic: “The effect of the secondary market on auction design is an interesting topic and so is a study about the switch that some countries have made, from one auction type to another, the reasons behind it and the consequences of it.”

We further explore this issue and its impact in our empirical analysis. Although no theoretical or empirical work exists on secondary market and auction mechanism choice, we wanted to explore a reasonable narrative based on the current theoretical analysis of auction mechanism choice. The current consensus in the literature is that the dominance of either auction formats (at least based on the expected revenue) depends on the specifics and is an empirical question (Ausubel et al (2014), Jackson et al (2006)). Hortacsu (2012), in a structural estimation framework, also could not find uniform dominating discriminatory format. The role of the secondary market and past experiences must have also given the auctioneer clues of dominance of discriminatory format under certain circumstances as “Most countries use a discriminatory auction (24) while nine countries use a uniform auction” in the sample of Brenner et al (2009).

The theoretical motivation for the auction choice should therefore be based on from auctioneer’s perspective; about his expectation about the influence of the secondary market outcome and other macro factors on one format dominating the other. Jackson et al outlined a scenario when discriminatory format may dominate the uniform price format in terms of revenue. According to them “in a situation where each bidder has a large difference between

marginal valuations for some objects, then we saw in Example 4 that it is also possible for the revenue of the discriminatory auction to exceed that of the uniform price auction.”

Although we do not observe the marginal valuations of bidders, one proxy for large difference in marginal valuation is the volatility of actual bids submitted by bidders. To check the association between the volatility of actual bids with pre auction secondary market volatility, we run a regression of the bid-volatility as dependent variable with auction type and pre auction secondary market volatility as independent variables along with some controls. Our detailed analysis is not reported here. But we find that the coefficient of the uniform auction dummy interacted with the secondary market volatility is significantly negative. It suggests that bidders have higher volatility of their marginal valuations when the auction format is discriminatory. It also confirms the intuition of Jackson et al that “there might be some relationship between the shape of individual demand curves and the revenue ranking of the two auction formats.”

A possible narrative of choosing different auction format based on the secondary market condition and other macro factors by the RBI may be the following according to the arguments of Ausubel et al (2014) and Jackson et al (2009). Jackson et al (2009) showed that discriminatory auction may generate higher revenue when the marginal valuations of bidders are further apart. If the secondary market volatility is higher it is expected that the bidders have procured their existing inventory at very different prices. This makes the value of existing inventory quite different for different bidders and hence generating the marginal valuation of additional units very different. This in turn will affect the revenue of the bidders and auctioneer can generate higher revenue by switching to discriminatory format when volatility is reasonably high in the secondary market.

Ausubel et al (2014) also showed that discriminatory format may dominate all equilibrium of the uniform price format in terms of both revenue and efficiency when bidders are symmetric private value auction. However if bidder asymmetry is allowed then uniform may dominate discriminatory format in certain situations. The differential inventory position, underwriting auction position and funding costs are some examples of factors which may

induce enough asymmetry amongst bidders.

The narrative above establishes a linkage between the auction choice and the bidder behavior and hence auction outcomes perhaps via some unobserved factors (like the funding costs). This should affect the bid-shading by primary dealers and hence affect the auction underpricing and hence auctioneer's revenue. These and perhaps other macro factors affect the RBI's auction mechanism choice are unobserved to the econometrician. Therefore simple OLS regressions of (say) bid shading is affected by such confounding factors and is inconsistent. As the propensity to adopt uniform or discriminatory type auction depends on the net difference in bid-shading or auction underpricing that might result from one particular auction design.

Empirically, this type of problem can be handled by a switching regression model (Heckman (1976), Maddala (1983), Woolridge (2014)). A switching regression model has a binary "switching" equation, which in our case represents the auction type choice by the RBI. It also has a continuous choice regression of (say) bid-shading choice by the primary dealers. Formally,

$$I^* = Z_i' \gamma + \varepsilon_i \tag{1}$$

$$y_{1i} = x_i' \beta_1 + u_{1i} \tag{2}$$

$$y_{2i} = x_i' \beta_2 + u_{2i} \tag{3}$$

where the observed choice of auction type is represented as I_i , where

$$I_i = 1 \text{ iff } I_i^* > 0$$

and

$$I_i = 0 \text{ iff } I_i^* \leq 0$$

The auction type choice as described above is modeled in a reduced form. As discussed in the theoretical motivation section, the auction type choice is probably result of an equilibrium where expectations of the potential bidder behavior in either format prompts the auctioneer to choose either uniform or discriminatory regime. The underlying variables which affects the equilibrium auction choice are represented by Z_i . As argued in the discussion earlier, we use pre auction secondary market variables such as secondary market volatility, trading volume and no of trades as the primary determinant of the auction choice.

The dependent variable y in equations (2) and (3) represents the final auction outcomes (like price pressure and total demand in auction) and bidder level outcome such as bid shading in uniform and discriminatory auction format respectively. Specifically y_{1i} is the primary dealer level bid shading (or auction level underpricing or bid cover) for the uniform auction regime, y_{2i} is defined accordingly.

The endogeneity between the auction type choice and the auction or bidder level choices are modeled by allowing the residuals from equations (2) and (3) to be correlated with the residuals in the auction choice equation, such that unobserved or missing variables in the auction choice equation are allowed to also affect the bid-shading or underpricing and auction level demand. Therefore the residual variance covariance matrix is non-diagonal as represented by:

$$COV(u_{1i}, u_{2i}, \varepsilon_i) = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{1\varepsilon} \\ \sigma_{21} & \sigma_{22} & \sigma_{2\varepsilon} \\ \sigma_{1\varepsilon} & \sigma_{2\varepsilon} & 1 \end{bmatrix} \quad (4)$$

Lee (1978) used this type of model to allow endogeneity between unionism and wage rates and Fang (2005) used this model to analyze the effect of underwriter reputation on yield among many others. More details about this type of treatment effect model can be

found in Maddala (1983) and Woolridge (2010).

Ignoring the joint dependence of the error terms will lead the OLS to be inconsistent as can be seen from the following observation:

The expected value of y_{1i} (bid-shading or auction underpricing or auction demand) is only observed depending on the auction regime and can be written as

$$\begin{aligned}
E[y_{1i}] &= E[y_i | I_i = 1] \\
&= E[y_i | I_i^* > 0] \\
&= E[X_i' \beta_1 + u_{1i} | Z_i' \gamma + \epsilon_i > 0] \\
&= X_i' \beta_1 + E[u_{1i} | Z_i' \gamma + \epsilon_i > 0]
\end{aligned} \tag{5}$$

Given the correlation structure in equation 4, the second term is does not have a zero mean which makes the OLS inconsistent. Under the joint normality assumption of the error terms it can be shown that

$$E[u_{1i} | Z_i' \gamma + \epsilon_i > 0] = \sigma_{1\epsilon} \left(\frac{\phi(-Z_i' \gamma)}{1 - \Phi(-Z_i' \gamma)} \right) = \sigma_{1\epsilon} \left(\frac{\phi(Z_i' \gamma)}{\Phi(Z_i' \gamma)} \right) = \sigma_{1\epsilon} \lambda_i \tag{6}$$

If we can estimate the above term and put it back in the $E[y_{1i}]$ equation above then OLS will yield a consistent estimate. Heckman (1976) suggested a two step estimation procedure where the inverse Mill's ratio (6) is first estimated by a probit regression and then the estimated Mill's ratio is used for consistent estimation of $E[y_{1i}]$ via OLS. The full information based maximum likelihood is also a possibility.

We can also use the above technique for counterfactual analysis to answer the following question: what would have been bid-shading (or underpricing) be during the uniform (discriminatory) regime if the auctioneer had used a discriminatory (uniform) format? To answer this question we need the following:

$$\underbrace{E[y_{2i}|I_i^* > 0]}_{\text{Hypothetical}} - \underbrace{y_{2i}}_{\text{Actual}} \quad (7)$$

Using similar arguments above it can be shown that, the hypothetical bid shading in the discriminatory regime had an uniform auction format be used can be written as

$$\begin{aligned} E[y_{2i}|I_i^* > 0] &= E[X_i'\beta_1 + u_{1i}|Z_i'\gamma + \epsilon_i > 0] \\ &= X_i'\beta_1 + \sigma_{2\varepsilon} \left(\frac{\phi(Z_i'\gamma)}{\Phi(Z_i'\gamma)} \right) \end{aligned} \quad (8)$$

The estimated inverse Mill's ratio can therefore be used to estimate the counterfactual outcomes.

5.1 Description of Results for Bid-Shading and Auction Underpricing

In table below we first report the probit equation of the first stage auction type choice equation. The dependent variable in that regression is a dummy variable which takes value 1 if the auction type was uniform and 0 if auction type was discriminatory. The explanatory variables are pre-auction secondary market variables like volatility, volume traded and number of trades.

Insert Table 8 here

Table 9 shows estimation results from second stage price pressure regression. Only auction specific variables such as auction size (notified amount), issue duration, pre-auction liquidity and volatility proxies and underwriting cut-off commission rate are included as independent variables. All the variables have desirable signs. Significant variables include auction size, pre-auction volatility and liquidity proxy and the underwriting cut-off with desirable signs;

a higher underwriting cut-off, signifying lower quality of the underlying issue leads to higher price pressure.

Insert Table 9 here

Table 10 shows estimation results from second stage bid-cover regression. Only auction specific variables such as auction size (notified amount), issue duration, pre-auction liquidity and volatility proxies and underwriting cut-off commission rate are included as independent variables. All the variables have desirable signs. Significant variables include auction size, pre-auction liquidity proxy and the underwriting cut-off with desirable signs; a higher pre-auction liquidity, signifying higher secondary market demand and lower trading costs leads to higher bid-cover.

Insert Table 10 here

Table 11 shows the second stage bid-shading regressions. The independent variables include auction level variables like duration, size (notified amount), pre auction liquidity and volatility proxy and underwriting cut-off. Bidder level variables are the amount of underwriting portion won (underwriting share) and a dummy for whether the bidder is a bank primary dealer or not. The underwriting cut-off is significantly positive for both auction type and has much higher impact during discriminatory regime. Bank primary dealer's shade their bids less than the standalone primary dealers during the uniform regime.

Insert Table 11 here

5.2 Counterfactual Analysis

For each outcome variable (auction underpricing, bid-cover and bid-shading), the counterfactual question we are interested in is: what would have been the outcome if the auction

format was uniform instead of discriminatory (or vice versa)? To answer this we need the following:

For counterfactual in the uniform regime we are interested in

$$\underbrace{E[y_{2i}|I_i^* > 0]}_{\text{Hypothetical}} - \underbrace{y_{2i}}_{\text{Actual}} \quad (9)$$

and for counterfactual in the discriminatory regime we are interested in

$$\underbrace{E[y_{1i}|I_i^* \leq 0]}_{\text{Hypothetical}} - \underbrace{y_{1i}}_{\text{Actual}} \quad (10)$$

As discussed earlier, we can estimate these counterfactual outcome by using the estimated inverse Mill's ratio. The results are reported in table III below.

Insert Table 12 here

Interestingly the counterfactual outcome does not rank one auction format for all three outcomes (bid-cover, underpricing and bid-shading). While a uniform format instead of a discriminatory format would have been better for lowering bid shading and auction underpricing, a discriminatory format would have been better instead of uniform format to increase auction demand (bid-cover). Specifically, bidshading in discriminatory auction format would have been higher by about 0.9% if uniform auction was used, and would have increased by 4.7% if discriminatory format was used instead of uniform format. We must add the caveat to this observation here that the counterfactual outcomes are based on the reduced form switching regression model under the joint Normality of errors assumptions. A full structural model of bidding behavior is necessary to get more accurate counterfactual predictions.

5.3 Devolvement: Switching Probit

The process of devolvement involves a binary outcome (devolve or not devolve) in an endogenous switching framework from uniform to discriminatory format and can be analyzed analogously following Aakvik, Heckman and Vytlačil (2000) in a switching probit framework.

Let I_i be the observed auction format choice as before.

$$I^* = Z_i' \gamma + \varepsilon_i \quad (11)$$

The devolvement happens according to the following process,

$$y_{1i}^* = x_i' \beta_1 + u_{1i} \quad (12)$$

$$y_{1i} = I(y_{1i}^* > 0) \quad (13)$$

where y_{1i} is the observed binary outcome of devolvement in the uniform auction format. y_{2i} , the observed binary outcome of devolvement in the discriminatory auction format is defined analogously

$$y_{2i}^* = x_i' \beta_2 + u_{2i} \quad (14)$$

$$y_{2i} = I(y_{2i}^* > 0) \quad (15)$$

As before u_{1i}, u_{2i} and ε_i follow a joint normal distribution which induces endogeneity;

$$COV(u_{1i}, u_{2i}, \varepsilon_i) = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{1\varepsilon} \\ \sigma_{21} & \sigma_{22} & \sigma_{2\varepsilon} \\ \sigma_{1\varepsilon} & \sigma_{2\varepsilon} & 1 \end{bmatrix} \quad (16)$$

which leads to a correlation matrix;

$$COR(u_{1i}, u_{2i}, \varepsilon_i) = \begin{bmatrix} 1 & \rho_0 & \rho_1 \\ & 1 & \rho_{10} \\ & & 1 \end{bmatrix} \quad (17)$$

This system is estimated using a full information maximum likelihood procedure following Heckman et al (2000).

We can also calculate the counterfactual outcome (what would have the probability of devolment if a uniform auction format was used instead of a discriminatory format and vice versa) using the estimated parameters. For example what would have been the probability of devolvement to those auctions in discriminatory format if a uniform format was used can be computed as

$$TU(x) = \Pr(y_1 = 1|I = 0, X = x) - \Pr(y_0 = 1|I = 0, X = x) \quad (18)$$

The first term measures the probability of devolvement in a uniform price format ($y_1 = 1$), given that the original auction format was discriminatory ($I = 0$). The second term measures the original probability of devolvement under the original discriminatory format $\Pr(y_0 = 1|I = 0, X = x)$.

Insert Table 19 here

Overall, based on the results above we find that our results are robust even after controlling for the possible endogeneity of the auction format choice by the RBI. Moreover, in a counterfactual analysis we find that neither auction format dominates the other confirming the theoretical motivation of Ausubel (2014) and Jackson et al (2006).

6 Conclusion

In this paper, we analyzed a unique two stage auction process in which the conduct of the main auction is preceded by a first-stage underwriting auction through which the auctioneer

obtains insurance against unfavorable outcomes in the second-stage main auction. We find that Stage 1 outcomes differ a great deal depending on whether the Stage 2 auction is a discriminatory auction (DA) or uniform price auction (UPA). Average underwriting premia are significantly higher when DAs are used in stage-2, as is the concentration of underwriting allocation. DAs also lead to greater bid-shading in the second round and consequent greater auction underpricing. We also find that the first stage underwriting auction outcomes provide significant information about the possible devolvement (tail risk) of the main auction, bid-shading in the second stage, and consequent main auction underpricing. We also find that while DAs lead to average underwriting benefits that are four times higher than under UPAs, they also have direct costs in the form of underwriting premia that are two times higher. Finally, we find that in certain counterfactual situations DA dominate UPA.

Table 1: Summary Statistics of the Auctions

This table provides summary statistics concerning the auctions in our sample such as the average auction size ("Notified Amount"), number of auctions that were devolved, and the duration of the securities being auctioned. Panel A looks at all 678 auctions in our sample. Panel B looks at that subset of 590 auctions for which we also have secondary market prices of the bonds being auctioned. Note that all 73 devolved auctions are also in Panel B.

	Uniform	Discriminatory	Total
Panel A: All Auctions			
Number of Auctions	511	175	678
Average Notified Amount	38.3	42.1	39.2
Number of Devolved Auctions	56	17	73
Average Auction Identified Price	98.8	99.2	98.9
Average Duration of Auctioned Security	12.6	12.8	12.7
Panel B: Auctions with Secondary Market Prices			
Number of Auctions	415	175	590
Average Notified Amount	39.8	39.7	39.8
Number of Devolved Auctions	56	17	73
Average Auction Identified Price	98.8	99.1	98.8
Average Duration of Auctioned Security	10.9	10.7	10.8

Figure 1: The Auction: A Hypothetical Example

This figure describes a hypothetical auction of INR 50 billion, as described in the text. The upper panel shows the bids received in the ACU underwriting auction that preceded the main auction. The vertical axis represents the commission rate bid (in INR per INR 100 face value of bonds) and the horizontal axis represents the aggregate quantity of bonds. The ACU underwriting auction was for half of the issue amount as shown in the figure. The lower panel shows the bids received in the main auction. The vertical axis represents the price bid per INR 100 face value of bonds while the horizontal axis represents the aggregate quantity of bonds. The total volume of bonds being auctioned was INR 50 billion, as shown in the figure, and the cut-off price was close to INR 99.5.

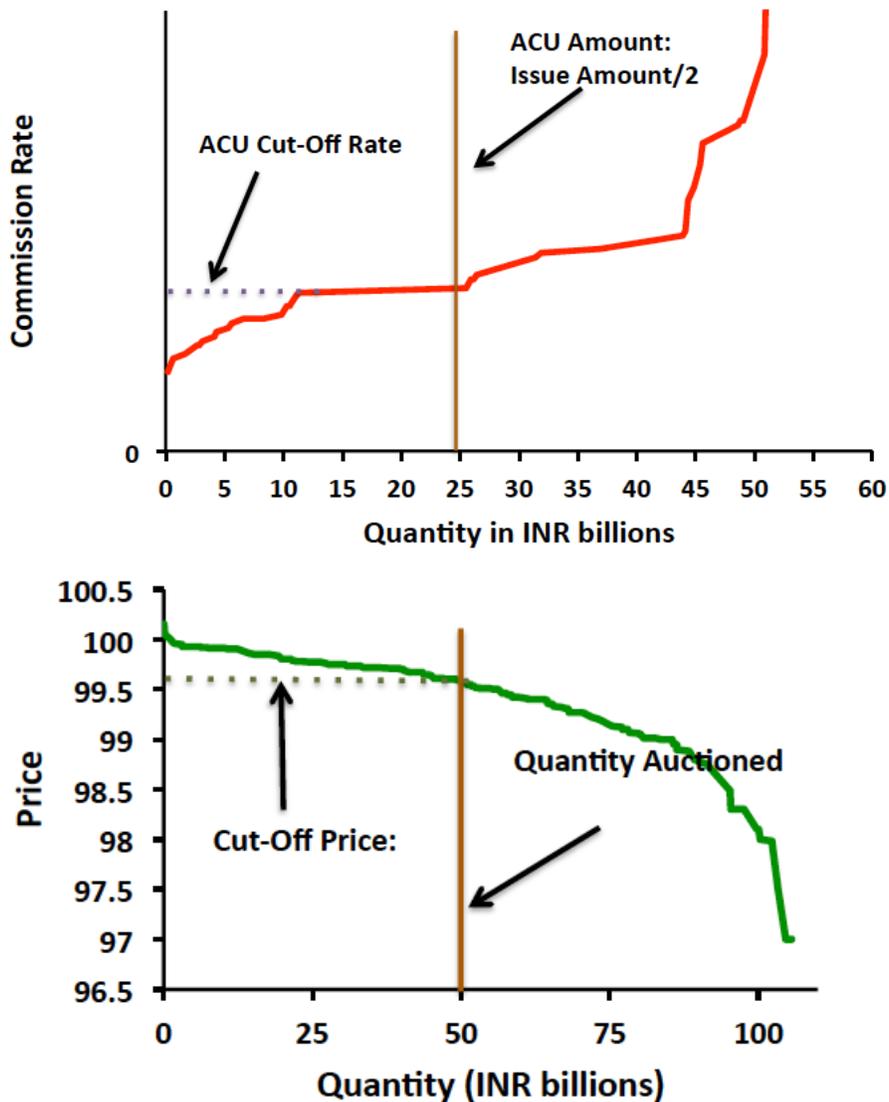


Figure 2: Price Behavior around Auction Day

This figure compares pre- and post-auction value-weighted secondary market prices to the price arising in the auction. The numbers are averaged across all auctions. The bands around each price represent 95% confidence intervals. VWP2daypre is the value weighted price two days before the auction, VWP1daypre is the value weighted price one day before the auction, VWPPreAuc is the value weighted price in the secondary market on the day of the auction before auction results were announced, Auction Price is the auction identified price, VWPPostAuc is the value weighted price in the secondary market on the day of the auction after auction results were announced, VWPPost is the value weighted price in the secondary market on the day after he auction.

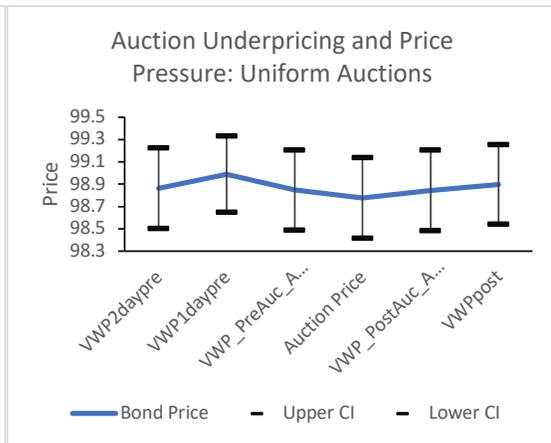
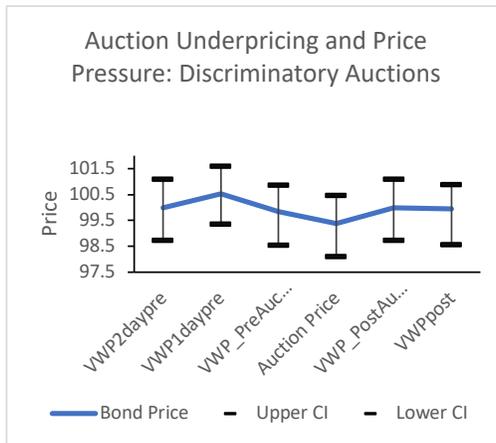
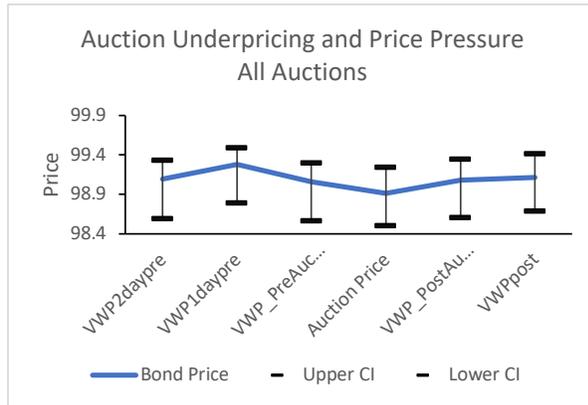


Table 2: Variable Definitions: Key Economic Variables

This table provides definitions of the key economic variables used in the various regressions in our analysis. As noted in the text, P_{t+1} refers to the value-weighted price in the secondary market day after the main auction computed using all the market trades in that bond on that day. *PostAuctionPrice* is the auction price in the secondary market on the day of the auction after the auction results are announced.

Economic Variables	Definitions
devolved	Dummy variable, takes on the value 1 if the auction devolved, and is 0 otherwise
bid cover	Total competitive demand divided by the notified amount
bid shading	$1 - (\text{value weighted bid submitted by dealer} / \textit{PostAuctionPrice})$.
Underpricing	$\ln(\textit{PostAuctionPrice} / \text{Auction cut-off price})$
Price Pressure	$\ln(P_{t+1} / \text{Auction cut-off price})$

Table 3: Summary Statistics of Dependent Variables

This table provides summary statistics for the dependent variables used in our analysis in Section 4.2. The variables are defined in Table 2.

All Auctions	Mean	Median	Std.Dev.
Bid Cover	2.35***	2.26***	0.53
BidShading (bps)	0.54***	0.29***	2.11
Price Pressure (bps)	0.20***	0.12***	0.01
Uniform Price Auctions	Mean	Median	Std.Dev.
Bid Cover	2.27***	2.2***	0.46
BidShading (bps)	0.43***	0.33***	1.87
Price Pressure (bps)	0.16***	0.12***	0.49
Discriminatory Price Auctions	Mean	Median	Std.Dev.
Bid Cover	2.67***	2.7***	0.68
BidShading (bps)	0.74***	0.26***	2.49
Price Pressure (bps)	0.32***	0.12***	1.11
Devolved Auctions	Mean	Median	Std.Dev.
Bid Cover	1.80***	1.76***	0.31
BidShading (bps)	1.06***	0.42***	2.11
Price Pressure (bps)	0.61***	0.19***	1.60
Successful Auctions	Mean	Median	Std.Dev.
Bid Cover	2.39***	2.29***	0.52
BidShading (bps)	0.54***	0.29***	2.11
Price Pressure (bps)	0.16***	0.12***	0.54

Table 4: Variable Definitions: Independent Variables

This table describes the independent variables used in the various regressions in our analysis. As noted, P_{t-2} refers to the value-weighted price in the secondary market two days before the main auction computed using all the market trades in that bond on that day.

Variable Name	Definition
<u>Underwriting Auction Variables</u>	
Underwriting bid Volatility	Standard deviation of ACU bids normalized by Pt-2, the value-weighted price 2 days before the main auction
Underwriting Share	ACU amount won by a primary-dealer bidder in underwriting auction normalized by notified amount
Underwriting Stopout commission rate	(Natural) log of the cutoff price in the underpricing auction
<u>Main Auction Variables</u>	
Auction Supply	(Natural) log of the amount being auctioned measured in INR billions
Auction Competition	The number of bidders in the main (i.e., the second-stage) auction
Duration	The Macaulay duration of the underlying bonds
<u>Secondary Market Variables</u>	
Secondary market volatility	Std dev of secondary market prices 2 days pre-auction computed using all trades and normalized by Pt-2
Pre-Auction Secondary Market Volume	The volume of secondary market trading (measured in INR billions) 2 days before the auction

Table 5: The Determinants of Devolvement

This table describes the results of a logistic regression where the dependent variable is 0 if the auction was successful and 1 if the auction ended up devolving. Robust standard errors are in the parentheses. As usual, *, **, and *** represent significance at 10%, 5%, and 1% levels, respectively.

	Spec1	Spec2	Spec3
Auction Competition		-0.000105*** (0.00004)	-9.36e-05** (0.00004)
Uniform Auction Dummy	0.00173* (0.001)	0.00172* (0.001)	0.00225* (0.001)
Duration		1.32E-05 (0.00004)	3.24E-05 (0.00004)
Auction Supply		0.000799 (0.001)	0.000756 (0.001)
Secondary Market Volatility	0.286 (0.37)	0.147 (0.36)	0.0842 (0.37)
Pre Auction Secondary Market Volume	-0.00327*** (0.001)	-0.00291** (0.001)	-0.00227* (0.001)
Pre Auction Number of Trades	4.17e-06** (0.000002)	4.57e-06** (0.000002)	3.78E-06 (0.000002)
Underwriting StopOut Commission Rate			0.000243* (0.0001)
Constant	-0.0130*** (0.0004)	-0.0121*** (0.0037)	-0.0105*** (0.0039)
Year Fixed Effects	Yes	Yes	Yes
Observations	590	590	590
R-squared	0.13	0.148	0.155

Table 6: Bid Shading by Primary Dealers

This table presents the results of OLS regressions on determinants of the bid shading by primary dealers in the second stage auction. The dependent variable is $(1 - \text{value weighted bids}/P_{PostAuc})$ by each bidder. Robust standard errors are in the parentheses. The * represents levels of significance * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

	Spec1	Spec2	Spec3	Spec4
Uniform Auction Dummy	-0.04*** (0.005)	-0.009*** (0.003)	-0.02*** (0.005)	-0.003*** (0.001)
Duration	0.002*** (0.0002)	0.0001 (0.0001)	0.003*** (0.0003)	0.0003*** (0.00004)
Auction Supply	-0.001 (0.005)	0.001 (0.003)	-0.05*** (0.006)	-0.003*** (0.001)
Underwriting Share			0.02 (0.021)	0.007*** (0.002)
Underwriting StopOut Commission Rate			0.006*** (0.0009)	0.0002** (0.0001)
Bank Primary Dealer Dummy			-0.0008 (0.0022)	-0.0007*** (0.0003)
Auction Competition			0.003*** (0.00028)	-0.00003 (0.00002)
Pre Auction Number of Trades		-0.000009 (0.000008)		-0.000002** (0.000001)
Pre Auction Secondary Market Volume		-0.0001 (0.0035)		-0.002*** (0.0005)
Secondary Market Volatility		3.004*** (1.06)		1.363*** (0.16)
Constant	-0.02 (0.023)	0.001 (0.014)	0.09*** (0.024)	0.02*** (0.004)
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	8,618	8,618	8,618	8,618
R-squared	0.033	0.015	0.068	0.094

Table 7: Auction Demand and Price Pressure

This table reports the results of OLS regressions in which the the dependent variable is the extent of price pressure in each auction measured as $\log(P_{t+1}/\text{Auction-identified Price})$ in the first two columns and auction demand measured as the bid cover in the main auction. Robust standard errors are in the parentheses. The * represents levels of significance * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

	Bid Cover		Price Pressure	
Underwriting StopOut Commission Rate		0.307 (0.3)		0.0002* (0.0001)
Auction Competition	0.01 (0.02)	0.024** (0.01)	-0.0001*** (0.00004)	-0.00009** (0.00004)
Uniform Auction Dummy	-2.473 (1.8)	-1.798* (1.1)	0.00172* (0.001)	0.00225* (0.001)
Duration	-0.0475 (0.07)	-0.0264 (0.04)	0.00001 (0.00004)	0.00003 (0.00004)
Auction Supply	-0.8*** (0.2)	-0.84*** (0.2)	0.0008 (0.001)	0.0008 (0.001)
Pre Auction Secondary Market Volume	-0.82 (1.0)	0.025 (0.3)	-0.003** (0.001)	-0.003* (0.001)
Pre Auction Number of Trades	0.0008 (0.001)	-0.0003 (0.001)	0.000005** (0.000002)	0.000004 (0.000002)
Secondary Market Volatility	-71.35* (39.5)	-140.5 (106.6)	0.147 (0.36)	0.0842 (0.37)
Constant	5.9*** (2.1)	7.96* (4.4)	-0.01*** (0.0037)	-0.01*** (0.0030)
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	590	590	590	590
R-squared	0.035	0.045	0.148	0.155

Table 8: First Stage Probit Regression of Auction Format Choice

This table provides first stage probit regression results of auction format choice of the two stage switching regression. The dependent variable is takes value 1 if the auction format is uniform and zero for discriminatory. All variable definitions are in the variable definition table in the paper. Robust standard errors are in the parentheses

Dependent Var: Uniform Dummy	
Duration	-0.066*** (0.01)
Auction Supply	-1.77*** (0.29)
Pre Auction Secondary Market Volume	-2.70*** (0.45)
Secondary Market Volatility	153.41*** (62.19)
Pre Auction Number of Trades	0.004*** (0.00)
Constant	6.84*** (1.12)
N	590
Pseudo R2	0.0943

Table 9: Switching Regression of Price Pressure

This table provides regressions of the determinants of price pressure in the second stage of the switching regression. The dependent variable is price pressure. All variable definitions are in the variable definition table in the paper. Robust standard errors are in the parentheses

	Determinants of Price Pressure			
	Uniform Auction		Discriminatory Auction	
Duration	0.000004 (0.00004)	0.0001 (0.00005)	0.0002*** (0.00008)	0.0002*** (0.00011)
Auction Supply	0.0007 (0.001)	0.0010 (0.001)	0.004** (0.002)	0.0037 (0.002)
Secondary market volatility	0.0580 (0.20)	-0.2178 (0.22)	1.24*** (0.49)	1.17*** (0.52)
Pre Auction Secondary Market Volume	-0.001** (0.001)	-0.0013 (0.001)	-0.0009 (0.001)	-0.0009 (0.001)
Underwriting stopout commission rate		0.0002*** (0.0001)		0.0001 (0.0002)
Constant	-0.0005 (0.003)	0.0001 (0.003)	-0.0159 (0.007)	-0.0166 (0.008)
<i>N</i>	590	590	590	590
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$				
LR test of indep. eqns. : $\chi^2(1) = 51.94$ Prob > $\chi^2 = 0.0000$				

Table 10: Switching Regression of Auction Demand

This table provides regressions of the determinants of auction demand in the second stage of the switching regression. The dependent variable is bid cover. All variable definitions are in the variable definition table in the paper. Robust standard errors are in the parentheses

	Determinants of Bid Cover			
	Uniform Auction		Discriminatory Auction	
Duration	0.00 (0.00)	0.01 (0.00)	-0.13 (0.11)	-0.10 (0.13)
Auction Supply	-0.4*** (0.07)	-0.4*** (0.06)	-0.34 (1.63)	0.06 (1.80)
Secondary market volatility	4.44 (17.56)	-27.54 (17.35)	-91.73 (368.65)	-72.32 (379.37)
Pre Auction Secondary Market Volume	0.02 (0.03)	0.06*** (0.02)	-0.35 (0.60)	-0.43 (0.59)
Underwriting stopout commission rate		0.02*** (0.01)		0.11 (0.26)
Constant	3.51*** (0.27)	3.92*** (0.23)	7.03 (6.84)	5.91 (6.96)
<i>N</i>	590	590	590	590

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$
 LR test of indep. eqns. : $\chi^2(1) = 66.08$ Prob > $\chi^2 = 0.0000$

Table 11: Switching Regression of Bid-Shading

This table provides second stage switching regressions results of the determinants of bid-shading. The dependent variable is bid-shading by primary dealers in the main auction. All variable definitions are in the variable definition table in the paper. Robust standard errors are in the parentheses

	Determinants of Bid Shading			
	Uniform Auction		Discriminatory Auction	
Duration	0.0001 (0.0002)	0.0003*** (0.0000)	-0.0004 (0.0004)	0.001*** (0.0001)
Auction Supply	0.008*** (0.003)	-0.003*** (0.001)	-0.02*** (0.006)	-0.008*** (-0.002)
Secondary market volatility	8.70*** (0.6)	1.05*** (0.1)	3.65* (2.2)	2.31*** (0.4)
Bank Primary Dealer Dummy	0.005*** (0.002)	0.000 (0.0003)	-0.02*** (0.004)	-0.002*** (0.001)
Pre Auction Secondary Market Volume	-0.02*** (0.002)	-0.002*** (0.000)	0.002 (0.003)	-0.0023*** (-0.0008)
Underwriting stopout commission rate		0.0002*** (0.0001)		0.003*** (0.0001)
Underwriting Share		0.01*** (0.003)		0.07*** (0.008)
Constant	-0.06*** (0.010)	0.01*** (0.002)	0.088 (0.020)	-0.05*** (0.006)
<i>N</i>	8618	8618	8618	8618
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$		Prob > chi2 = 0.0000		
LR test of indep. eqns. :		chi2(1) = 27277.32	Prob > chi2 = 0.0000	

Table 12: Counterfactual Predictions for Auction Demand, Price Pressure and Bid Shading

This table provides counterfactual predictions of bid shading, price pressure and auction demand based on the respective switching regression outputs as described in equation (9) and (10). t-statistics of the hypothesis that the counterfactual differences are not different from zero are reported in the parentheses

Panel A: Bid Cover Counterfactual				
Price Pressure Counterfactuals		Counterfactual Format		
Original Auction Format	Uniform	t-stat	Discriminatory	t-stat
Uniform Auction			-1.83%	(-35.464)***
Discriminatory	1.26%	(1.869)***		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Panel B: Price Pressure Counterfactual				
Bid Cover Counterfactuals		Counterfactual Format		
Original Auction Format	Uniform	t-stat	Discriminatory	t-stat
Uniform Auction			0.16%	(-5.785)***
Discriminatory	0.17%	(3.42)**		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Panel C: Bid Shading Counterfactual				
Bid Shading Counterfactuals		Counterfactual Format		
Original Auction Format	Uniform	t-stat	Discriminatory	t-stat
Uniform Auction			-4.7%	(-310.05)***
Discriminatory	0.87%	(2.55)**		

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Table 13: Devolvement : Switching Probit

This table provides regressions of the determinants of devolvement price by RBI. The dependent variable is percentage price difference (RBI cut-off-Counterfactual cutoff/Counterfactual cutoff). The independent variables are various auction level and pre auction secondary market variables. The variable prebond counterfactual defined as the ratio of pre-auction secondary market price to the counterfactual price. Robust t-statistics are in the parentheses

Panel A: Determinants of Devolvement				
	Uniform Auction		Discriminatory Auction	
Duration	-0.08*** (0.03)	-0.06** (0.03)	0.02 (0.03)	0.03 (0.04)
Auction Supply	0.21 (0.31)	0.32 (0.31)	0.73 (0.61)	1.15 (0.84)
Secondary market volatility	191.8*** (49.6)	134.33*** (57.0)	201.02*** (73.1)	210.3*** (76.2)
Pre Auction Secondary Market Volume	-0.26 (0.25)	-0.26 (0.25)	-8.19 (8.19)	-8.56 (8.47)
Underwriting stopout commission rate		0.04*** (0.02)		0.09 (0.12)
Constant	-1.43 (1.10)	-1.72 (1.11)	-5.44*** (2.54)	-6.72** (3.09)
<i>N</i>	590	590	590	590
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$				
LR test of indep. eqns. : $\chi^2(1) = 222.14$ Prob > $\chi^2 = 0.0003$				

Panel B: Devolvement Counterfactual				
Underpricing Counterfactuals	Counterfactual Format			
Original Auction Format	Uniform	t-stat	Discriminatory	t-stat
Uniform Auction			16.10%	(16.31)***
Discriminatory	8.50%	(21.51)**		

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