Financial Intermediaries, Market Power and Asset Prices in Treasury Securities

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Abstract

This paper analyzes the effect of competition among primary dealers on asset prices and liquidity provision in the treasury market. We analyze this issue using a unique dataset in a novel setting of entry of new primary dealers. In both reduced form and structural estimation settings we find that primary dealers improve the liquidity provision in terms of lower bid-shading after new primary dealers' entry. Using a structural model of strategic bidding under asymmetric information, we find that the liquidity provision as measured by (lower) bid-shading by the primary dealers improve by about 5 basis points, equivalent to about INR 20 million per auction. We link the structural estimates of market power of primary dealers with post auction secondary market pricing and document significant impact of heterogeneity of intermediaries' market power on asset prices in the secondary market. One standard deviation increase in the structural estimate of the intermediary market power leads to about 4.5 basis points increase in secondary market prices.

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1 Introduction

A recent and growing literature (He et al (2013, 2017), Haddad and Muir (2020)) emphasize on the role of intermediaries in asset prices in various financial markets (equity, bond, CDS, government securities etc.). Initial empirical findings document that intermediaries are the marginal investors in many asset markets, and their marginal value of wealth is a plausible pricing kernel for a broad cross section of securities (He et al (2017)). Given such high importance of the intermediaries on determination of asset prices, the role of competition amongst the financial intermediaries and its impact on asset prices and liquidity provision are questions of first order interest.

Primary dealers act as the financial intermediaries and play an important role in market making, price discovery and liquidity provision in both the primary and secondary markets for government securities. Using a unique dataset, this paper aims to analyze the effect of competition on the primary dealers' incentives to provide liquidity in the primary market of the Indian government securities. Haddad et al (2020) argue that the empirical analysis of intermediary asset pricing is riddled with identification challenges. We use the publicly announced entry of a new primary dealer in the Indian Government Securities market in a reduced form analysis with exogenous shocks, as well as in a structural model of bidding in the treasury auction (Hortacsu et al (2010)), to address the issue of market power of financial intermediaries and its impact on both within auction and post auction secondary market asset prices and liquidity.

The determination of the marginal utility of wealth (valuations) of the primary dealers is an important component in the asset prices (He et al (2017)). Our structural estimation procedure recovers the distribution of the unobserved valuations from the observed bidding data, which helps evaluate the impact on asset prices. The presence of market power originating from the private information and other market characteristics may induce the intermediaries to shade their bids from their true marginal valuations in the primary market of treasury securities (Hortacsu et al (2018), Kastl (2016)), which in turn may lower liquidity provision by the primary dealers. Therefore, higher market power may impede the market quality and intermediation services by lowering liquidity in both the primary and secondary market. This in turn affects the asset prices. The structural estimation procedure gives us an estimate of the market power of the intermediaries as well as the distribution of privately observed marginal valuations of the intermediaries and other primary market participants. Using these structural estimates we evaluate the impact of competition (through the lens of the entry of a new primary dealer) on asset prices and liquidity provision by primary dealers.

We find that the primary dealers improve their liquidity provision (as measured by lowered bid-shading) post entry. Our structural measure of ex-ante bid shading goes down by approximately 5 basis points post entry. This is equivalent to an improvement of about INR 20 million revenue to the central bank.

We also link the structural estimate of the market power in the primary market with post auction secondary market prices of the underlying security. We find that one standard deviation increase in the average market power of primary dealers in the primary market auction leads to about 4.5 basis point increase in the post auction secondary market prices. To the best of our knowledge, we are the first paper to document the linkage of structural estimates of market power in the primary market with secondary market prices in the treasury securities.

The role of competition on liquidity supply and asset prices is a significant area of theoretical research on financial intermediation (Kyle (84,89), Vayanos (2012)). When information is asymmetric, imperfect competition lowers liquidity (Vayanos (2012)), as both liquidity demander and suppliers consider their effect on price and trade less aggressively in response to their privately observed signals about the underlying security and their liquidity shock. Since the primary dealers are the marginal investor and their privately observed marginal value of wealth is a major component of the pricing kernel (He et al(2017)), the market power and competition among the primary dealers is expected to be a major driver for liquidity and asset prices in the treasury securities market. In the treasury securities market, primary dealers' private information comes from the observation of the order flow from customers orders (Hortacsu and Kastl (2012)) and through better expertise and technology of information production. The focus of this paper is to identify and estimate the role of market power of the primary dealers and evaluate the effect of competition on asset prices.

The market-making and liquidity provision are cited as major advantages of the primary dealer system across the world (Arnone (2005)). The primary dealers are also expected to provide market information to the central bank and make the market through active trading. If foreign firms are allowed as primary dealers, they may also bring their expertise and international clientele, which may in turn improve efficiency and competition in the market, which in turn may improve liquidity. A primary dealer system may also reduce risk and risk management burden for the central bank and help during market failure.

We use a unique setting of treasury auction in India where primary dealers explicitly provide insurance against auction failure and help mitigate the risk management burden of the central bank[1]. We evaluate the impact of entry of a foreign primary dealer in the Indian treasury securities

[1] We discuss the underwriting system in the treasury bond market in India in detail in the next section.

market to evaluate the relative benefit on market making and liquidity provision.

The entry of an experienced primary dealers, active in other mature markets will also bring their financial intermediation expertise, producing more information, which may mitigate the risk of market making by other primary dealers. Consistent with this hypothesis, we find that the liquidity provision by primary dealers on a successful auction held on the same week of a failed auction (a stress period) improves after the entry.

The primary dealer (PD) system also comes with certain disadvantage. The PD system's main disadvantage is the distortion on competition and an uneven playing field that gives perhaps an unfair advantage to a group of market participants. Many PDs have strong international presence and informational advantage which in turn may lead to an oligopolistic market.

The impact of competition amongst the financial intermediaries on liquidity provision therefore is not clear. On the one hand, increased competition may lower liquidity as higher competition may reduce their margin and PDs may demand higher premium for providing liquidity. Higher competition, on the other hand, may help improve liquidity through the information transmission channel. If the new entrants have valuable information, then in a common value setting, it is optimal for the incumbents to reveal more of his own signal to induce everybody to reveal more information through their demand curves (Vives (2011)). Intuitively, more information revelation improves the correlation in the common value setting and reduces winner's curse. If more information is revealed through the primary dealers, it will improve liquidity in the market.

While presence of primary dealers is widespread in the worldwide financial markets (Arnone (2005)); little is known about the impact on competition due to entry of new primary dealers on the asset prices in primary and secondary market of the government securities, perhaps due to lack of available data. This paper uses an unique proprietary dataset and entry of new primary dealer in the government securities market in India to evaluate the benefits of primary dealer competition on asset pricing and liquidity provision.

The primary market auction of treasury securities affect the secondary market through various channels. Besides information production about the underlying securities overall demand, the secondary market prices may link to the primary market due to presence of short squeezes (Nyborg and Strabulev (2004)). Bidders who have pre-existing short positions need to cover their position in the auction or post auction secondary market. Market participants with long positions can take advantage of this situation by charging exorbitant prices (shorts squeeze). Long players in such a situation have upward sloping valuation schedule. If bidders establish long positions and have market power during the auction, then they may affect the post auction secondary market prices. Cooper and Donaldson (1998) formalized Kyle's (1984) hypothesis that even small long players will be able to free ride on the short squeeze by a large long player. Nyborg and Strabulev (2004) also showed that in this kind of a scenario the bidders will have private values in the auction, even though the underlying security is common value in nature.

The Indian government securities market is a mature market and function the same way as the US G-Sec market. There are multiple weekly auctions of government securities in the primary market for treasury bills, federal and state government bonds. There is also a very active and liquid secondary market of government securities (Fleming, Sagar and Sarin (2018), Gupta, Sundaram and Sundaresan (2020)). The primary dealers play a major role in both the primary and secondary market.

A notable characteristic of the Indian primary dealer system is the presence of heterogeneity amongst the primary dealers. The Indian primary dealer system has two types: bank primary dealers (bank PD) and standalone primary dealers (standalone PD). The bank PDs are defined as PDs with a commercial banking operation (like Axis Bank, Citi Bank, etc.). The standalone PDs are financial intermediaries who do not have a commercial banking operation (STCI, Goldman Sachs, Morgan Stanley, etc.). The banks PDs can use government securities in maintaining their credit requirement ratio (statutory liquidity ratio (SLR)) with the central bank (Reserve Bank of India) on their balance sheet. Ceteris paribus, a bank primary dealer therefore can hold a treasury security longer on their balance sheet than the stand-alone primary dealer. This affects the relative aggressiveness and incentives of the bank primary dealers to sell a security acquired through a treasury auction in the secondary market. In turn, this affects their relative competitiveness and liquidity provision incentives in both the primary and secondary market.

The heterogeneity of the two types of PDs manifests through their respective balance sheets into the pricing of the underlying securities. The role of heterogeneity within the intermediary sector is an unexplored area and deserves special attention for its asset pricing implications (He and Krishnamurthy (2018)). The unique data set helps us shade lights on this issue through the lens of competition. We find that the bank primary dealers provide more liquidity and submit relatively more competitive bids in the primary market of treasury securities auctions. Our structural estimate of the bank primary dealers market power in the treasury auction has significant impact in lowering the prices in the post auction secondary market.

We use bid-shading as a measure of market power and liquidity provision by the primary dealers in the primary market of treasury securities. Bid-shading is the amount that a bidder lowers his bid relative to his privately observed marginal valuation of the underlying security for sell. Higher bid-shading by the primary dealer will make the central bank leave more money on the table while selling the underlying treasury bond. Higher bid-shading by the bidders steepens the aggregate demand curve relative to the fixed supply during auction and suppress the price (increase the yield) of treasury securities. The role of bid shading as defined below is important in understanding the impact of market power and asymmetric information on the pricing kernel and primary dealers' marginal willingness to pay. In the primary market the primary dealers play the central role of liquidity provision and underwriting. It is expected that the primary dealers 'shade' their bids from their marginal willingness to pay (MWP) (Nyborg, Rydqvist and Sundaresan (2002), Hortacsu and McAdams (2010)).

$$Bid = MWP - Bid\ Shading \tag{1}$$

The bid shading term in the primary auction depends on the level of competition and the level of asymmetric information. It is worth noting the similarity of this with the pricing equation of an oligopolist facing uncertain demand : $Ep = c'(q) - \theta Ep'(q)q$, where θ is a measure of market power. The bid-shading term therefore depends on the market power of the bidder facing uncertain bidding functions from its rivals (Klemperer and Meyer (1989)). The privately observed marginal willingness to pay (MWP) is equivalent to the marginal value of the bidders.

We use two measures of bid-shading. An ex-post measure which only uses the actual bid data by bidders and its relative comparison to the secondary market prices. We take the value weighted average bid submitted by each bidder and compare it to the post auction value weighted secondary market prices to impute an ex-post measure of bid-shading (Nyborg, Rydqvist and Sundaresan (2002), Malvey and Archibald (1998)).

However, the ex-post measure of bid-shading does not give us the true extent of the bidder's true marginal willingness to pay for various reasons. First, the $ex-post$ measure uses the post auction secondary market prices as a comparison of the true market value for each bidder. However, treasury auction bidders being highly heterogeneous, often differ depending on their inventory holding horizon. For example, many financial institutions like large insurance companies may follow a buy-and-hold strategy for whom the immediate post auction secondary market price may not be the right benchmark to evaluate their willingness to pay. Even among the primary dealers, bank affiliated primary dealers (Bank PDs) may have different incentives, and may need a different benchmark relative to stand-alone primary dealers, as Bank PDs can hold the treasury securities to offset their SLR (statutory liquidity ratio) requirements. Second, the strategic impact of market power and the nature of asymmetric information among bidders may impact the actual bidding behavior of different groups of bidders (primary dealers versus insurance companies versus retail) differently. We therefore need a structural model to estimate the $ex-ante$ bid-shading for individual bidders, which may incorporate some of these issues in the actual bidding behavior.

The identification and estimation of the ex-ante bid shading term is therefore crucial in analyzing the impact of competition on liquidity provision in the primary market. The bid shading term is complicated by the strategic behavior of the bidders in the primary market of treasury auctions. The marginal willingness to pay (MWP) is privately observed by the bidders and econometrician only observes the actual bids. The actual bid depends on their strategic response of the presence of asymmetric information and the level of competition in the auction as manifested via the bid shading term. Identification and estimation of a structural model of strategic bidding (Hortacsu and McAdams (2010)) is necessary to recover the marginal willingness to pay for each bidder from the observed bid distribution. We follow a similar procedure to estimate the marginal willingness to pay for each bidder to analyze the impact of entry on bidding behavior in the primary market as well as its influence on both the primary and secondary market liquidity. The ex-ante measure has a specific term to control of the market power of the bidders in their bidding behavior. That measure is therefore helpful in evaluating the impact of entry of new primary dealers on market power of individual bidders.

We find that the structural estimation of market power of the primary dealers has a significant upward impact in post auction secondary market prices. This is plausible according to Nyborg and Strebulaev (2004), as player with market power may generate short squeeze which puts upward pressure on the prices. To the best of our knowledge our paper is the first to empirically link the structurally estimated market power to secondary market activities.

The primary market outcome impacts the endowments shocks and acts as a major driver on the secondary market liquidity (Pasquairello and Vega (2009)). The authors argue that the market maker, to hedge against the adverse selection induced by informed traders, lower liquidity (by demanding extra spread) to clear the asset. For the recently issued (on-the-run) security, the informed speculators receives an (exogenous) endowment shock through the primary market auction, which in turn lowers the adverse selection component and hence improving liquidity provision by market makers. In our setting, the presence of more primary dealers (through entry of new dealers) as speculators may increase higher informativeness of the order flow and in turn improves liquidity. We find that the amount won by the primary dealers as well as the structural estimate of market power in the primary market auction has significant impact on post auction liquidity.

Intuitively, the impact of entry by foreign primary dealers like Goldman Sachs, Nomura etc. (and other primary dealers) in the primary market affects the price discovery and liquidity through the following channels. First, the impact of new primary dealers affects the information production in the primary market and hence the winner's curse in the bidding behavior. Experienced primary dealers like Goldman Sachs, Nomura, who are also active in other mature markets, potentially comes with a better technology of information production. As argued by Vives (2011), more information revelation improves the correlation in the common value setting and reduces winner's curse. If more information is revealed through the primary dealers, it will lead to improved liquidity in the market.

Second, since the covering of the short position will be more costly, the potential of a short squeeze increases when bidding against new primary dealers. Bidders should bid more aggressively when a new primary dealer enters in the auction to increase their chances of getting long. Also since auction generally settles at a lower price than the post auction secondary market (Nyborg and Sundaresan (1996), Gupta et al (2020)), (short) bidders would like to cover some of their short positions in the auction than in the post auction secondary market.

Third, the liquidity in the after market should improve as market makers now trade with another competitor. The increased competition brings in more information in the secondary market and hence less adverse selection costs. Higher liquidity in the post auction secondary market in turn should lower the indirect costs of holding the security and make bidders more aggressive in the primary market.

Our paper makes several contributions to the literature. A recent literature (He et al (2013, 2017), Haddad and Muir (2020)), has argued and documented the role of intermediaries in the asset prices in various financial markets (equity, bond, CDS, government securities etc.). Initial empirical findings document that intermediaries are the marginal investors in many asset markets and their marginal value of wealth is a plausible pricing kernel for a broad cross section of securities (He et al (2017)) at the macro level. Since the financial intermediaries enjoy market power due to their size and informational advantage, the role of competition and industrial organization of the intermediaries and its impact on asset price and liquidity are important first order questions and hitherto unexplored. Using a unique dataset and entry of new primary dealer and structural model of bidding for the primary market of government bonds, we aim to shade more light on this question. While He et al and subsequent authors analyze the macro asset pricing implications of financial intermediaries, we look at the impact of competition and entry of financial intermediaries on asset prices and liquidity at the micro level for individual treasury security auction.

The liquidity in the secondary market of the government bond and various anomalies like on-the-run off-the-run spread is an active area of research. A large empirical literature (Amihud and Mendelsen (1991), Krishnamurthy (2002), Strebulev (2002), Fleming (2003), Boudouk and Whitelaw (1993)) has reported that securities with nearly identical cash-flows trade at different yields and with different liquidity. Pasquariello and Vega (2009) related this phenomenon to the endowment shocks to the market participants that is generated in the auctions in the primary market of government securities. The main focus of our work is to structurally estimate those endowment shocks from the primary market and relate it to the secondary market liquidity to uncover the role of information production and competition amongst the financial intermediaries on the liquidity in the primary as well as secondary market. In this process, we model and estimate a structural model of bidding in the primary market from the detailed bidder level data to uncover the distribution of unobserved valuations of the bidders in the primary market.

The identification and estimation of the structural model of bidding in the treasury auction is an active area of research in industrial organization (Hortacsu and McAdams (2010), Hortacsu and Kastl (2012)). This literature primarily focus on identifying the bidder valuations and auction revenue and relate it to the counterfactual analysis of different treasury auction format (uniform vs discriminatory). We are interested in evaluating the role of competition and its impact on the secondary market liquidity. According to Kastl (2016), evaluating the impact of competition on the rents enjoyed by bidders is an interesting question for further research. We analyze that question through the lens of entry of Goldman. We also analyze the impact of competition in the primary market and market power on secondary market asset prices and liquidity.

The role of auction format (uniform versus discriminatory) and its implication on revenue, the likelihood of short squeezes, post auction volatility or pre auction pricing (from the when issued market) is an actively debated literature (Back and Zender (1993), Nyborg and Sundaresan (1996), Nyborg and Strebulaev (2004)), who either theoretically or through reduced from empirical analysis documents the inter-linkages. In this paper, we formulate a structural model of bidding in the primary market and analyze the change in the competition structure of the financial intermediaries (primary dealers) to analyze the impact on the market quality. Our structural model of bidding will help us conduct various counterfactual analysis.

The rest of the paper is organized as follows: next section describes the institutional details of the Indian treasury security auction. Section 3 describes the data and reports some preliminary descriptive statistics on the impact of competition on the primary and secondary market liquidity. Section 4 describes the methodology to establish the causal implications of competition. Section5 describes some reduced form evidence. Section 6 outlines a structural model of bidding in the primary market and outlines an algorithm for estimation, report results on structural estimation of marginal valuations and analyze the role of competition on liquidity provision and asset prices in post auction secondary market. Section 7 gives conclusion.

2 Institutional Details: The Indian Treasury Auctions System

The Indian treasury market follows a weekly schedule of auctions in the primary market. The secondary market has an over the counter as well as an electronic order matching system and highly liquid (Fleming et al (2016)). Primary market auctions of short-term government securities (TBills) are conducted via periodic (weekly) auctions. Primary market auctions of treasury notes and bonds (greater than one year maturity) for government debt (G-Secs) are generally conducted for two types of securities: new issues and reissues. New issues are those securities that are auctioned for the first time. Reissues are those securities that were previously issued and opened up again for a primary market auction to sell additional amounts of the same security. In a reissue, with the coupon set and fixed at the original auction, the auction is conducted in price terms (as mentioned, new securities are auctioned in yield terms). The reissues are already trading in the secondary market and have an active reference price. The debt manager of the government (Reserve Bank of India (RBI)) generally prefers to use reissues over new issues for raising capital because of the presence of a liquid secondary market. In fact, like the rest of the world, most of the auctioned securities for our data period are reissues. In this paper, we only look at the reissue auctions of treasury notes and bonds for homogeneity and availability of pre-auction secondary market data.

The primary dealer system which was first initiated in the US in the 1960s, spread to India starting in the 1990s. The Reserve Bank of India (RBI) introduced the auction method of primary issuance of government securities in June 1992[2] and the first price based auction was conducted on May 11, 1999. The Fiscal Responsibility and Budget Management act (FRBM (2003)) mandated fully market determined process and withdrawal of RBI as a underwriter of last resort starting April 1st 2006 in the primary market of government securities. The RBI constituted various committees and issued guidelines to strengthen the primary dealer system. Primary dealer's cannot have step down subsidiaries to protect the primary dealers from the spillover risks from other business.

Shorting of government securities is permitted for risk management by the primary dealers. RBI also extends liquidity support to PDs. As mentioned earlier, commercial banks are allowed to undertake primary dealer activity as a separate department with audit trails. They can also keep the government securities on their book towards meeting various liquidity ratio. The primary dealers are required to participate in the government securities auction as well as maintain a minimum success ratio and bid-cover ratio. The RBI publishes various statistics about the primary dealer system in its annual report on trends and progress of banking in India[3]. It has a specific subsection

[2] see "Two Decades of Primary Dealer Operations in India" by Rajaram and Ghose (2015) for more details.

[3] For example see on RBI website for 2012-13: https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/0RTP21112013_F.pdf : refer to page 187 onwaryds of this report for the primary dealer section.

on the performance of the primary dealers and any major changes.

RBI also mandates the primary dealers to act as market maker and provide depth and liquidity in the secondary market. India has an anonymous order matching system of screen based trading called NDS-OM since September 2005. According to Rajaram and Sahana (2015), PDs prefer the OTC market for selling securities while buying mostly from the anonymous order matching platform NDS-OM and treasury bonds consists of about 90% of the total buying of the PDs.

In table 1A we give annual holding patterns of various dated central government securities. The commercial banks are the majority holders of the treasury bonds. The standalone primary dealers hold a small portion of the treasury bonds on their book suggesting that they flip most of their winning amount in the secondary market. In table 1B we give various performance metrics of the primary dealers. The PD success rate is over 40% for the data period. They also submit enough bids to cover the entire issue size in the primary market as measured by the bid to cover ratio.

INSERT TABLE 1 ABOUT HERE

The Indian primary market of G-Secs (notes and bonds) has a unique two stage process since 2006 (Fleming et al (2016), Gupta Sundaram and Sundaresan (2020)). In the first stage of the auction, the underlying issue is explicitly underwritten by the primary dealers against any possible auction failure. In this stage primary dealers compete for the underwriting commission via a discriminatory auction. In the second stage, all bidders (both primary dealers and the rest of the market) compete for the underlying issue via either a Uniform or Discriminatory price auction. The second stage therefore is like the standard auction in the US treasury securities system. If there is not enough demand in the second stage auction of the notes and bonds, the central bank decides to set a high enough price of their choice and the shortfall of demand (at that pre-set price) is devolved to the primary dealers proportionately based on the amount underwritten by the primary dealers in the first stage. The devolvement price of the auction is more like a secret reservation price set by the central bank after it observes all the bids. This is not know prior to the submission of the bids. In our sample, about 6% of the issues were devolved. In case of no devolvement (successful auctions), the primary dealers keep the commissions won in the underwriting auction.

3 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. The secondary market data contains time stamped trades of all trades of government securities. It does not have bid-ask spread or any identifier for the buyer or seller initiated trades.

The primary market dataset contains the auctions of the long term government bonds (G-Secs) of $2, 5, 10$ and 30 year maturities. 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 data set of the government bonds have 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 and other bidders participating, and individual price–quantity pair bids by each bidder and the cutoff auction price; the highest price at which demand equals or exceeds supply.

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 over time. We look at the auctions held around the Goldman entry date. Goldman Sachs entered as a primary dealer in the Indian treasury market in April 2011. We look at all auctions held for the period $2010 - 2012$, i.e., we look at auctions held one year before to one year after Goldman entry. We have 129 auctions held prior to Goldman entry and 217 auctions held post Goldman entry[4]. All auctions during this period were auctioned off via an Uniform price format. The secondary market data contains intraday trading information (timestamped trade with prices and quantities) for each trade for each bond.

We also observe the cutoff commission rate at which the entire auctioned quantity is underwritten and whether the underlying issue was devolved or not in the primary market auction.

4 Methodology

We shall use a combination of two methods. A quasi-natural experiment based on the staggered entry of new bidders as primary dealers and a structural estimation of the entry and bidding behavior in the auctions. Our main variables of interest are the liquidity in the primary and secondary market and bid shading in the primary market.

[4]The RBI started holding multiple auctions on the same week during the later period, this leads to increased number of auctions in the later period than in the earlier period.

4.1 Quasi Natural Experiment of Entry of New Primary Dealers

As outlined earlier in the introduction, the Indian G-Sec market observed a change in the primary dealers' compositions over time. There are two types of primary dealers in the Indian G-Sec market: the standalone primary dealers (standalone PD) and the bank primary dealers (Bank PD). The standalone PDs have no other banking operations and bank PDs can also have regular commercial banking operations. For example, the largest commercial private sector bank in India: HDFC bank also has a primary dealer business and is a bank PD. A list of bank and standalone PDs are given in the table below.

INSERT TABLE 2 ABOUT HERE

There has been periodic entry of new primary dealers in the PD system as well as move from standalone PD to bank PD in India. For example, Goldman Sachs joined as a new standalone primary dealer in April 2011, Nomura joined in September 2009, Axis Bank joined in April 2010, etc. The dates of entry of new primary dealers can be found in the RBI annual report on banking and is summarized in table 3. The entry of the new primary dealers changed the competition in the primary dealer system, and we shall use it as a natural experiment to analyze the impact through a difference -in-differences framework.

INSERT TABLE 3 ABOUT HERE

To evaluate the impact of competition amongst primary dealers on market liquidity we use a multi-pronged approach. We first do some descriptive analysis. We first look at some conditional analysis of the impact of new primary dealer's entry on liquidity provision measures by primary dealers in the primary market. We control for market and issue characteristics as well as bidder types (bank primary dealer or not) and various fixed effects. We find that, at the auction level, the number of trades and secondary market volume of trades post auction goes up significantly after the new primary dealer's entry relative to its pre-auction number of trades and volume. This signifies an improvement in the secondary market liquidity of the underlying government, perhaps due to improved information production due to increased competition after the entry of new PDs.

We then analyze the impact on the bidding behavior and provision of liquidity by primary dealers in the primary market auction. We find one important ex-post measure of liquidity provision by the primary dealers, as measured by the bid-shading, goes down significantly in the treasury bond auctions post entry of new PDs. The number of bid points submitted by individual bidder in every auction (the number of price-quantity pair in a bidder specific demand curve) as well as the variance of the bidpoints submitted both go down significantly post Goldman entry. All these measures points to improved liquidity provision by primary dealers in the primary market of treasury securities auction due to increased competition.

To address the potential issue of endogeneity and confounders or omitted issue characteristics, we employ a second empirical approach. We exploit the nature of the impact of the primary dealer competition in treasury bonds issuance. Here the unique market structure of the Indian government bond auctions comes into play. The Indian treasury auction issuance process allows two types of primary dealers: bank primary dealers and standalone primary dealers. The bank primary dealers (bank PD) are those who also have commercial banking operations. Bank of America, Axis Bank, Citi Bank are examples of bank PDs. The rest like Goldman Sachs, Nomura, STCI etc. are stand alone primary dealers. The Banks PDs have one advantage, they can use the amount won in the treasury auctions towards meeting their requirement for statutory liquidity (SLR) maintenance as mandated by the RBI. This affects the budget constraint and different holding patterns for the bank PDs; they need not flip the amount won in the auction immediately and can hold it longer on their balance sheet. This creates a clear heterogeneity amongst the primary dealers. The bank PDs are therefore less concerned about the underlying flipping value of the underlying security over the next day(s) of the auction. The standalone primary dealers on the other hand do not want to hold the underlying security on their balance sheet for too long to have enough liquidity to participate in subsequent auctions. The role of information about the underlying flipping value is therefore has more significance for the standalone primary dealers relative to the bank PDs. Hence the information discovery channel of the entry of new primary dealers (Vives (2011)) will affect the bank PDs less relative to the stand alone PDs. The bank PDs should therefore be affected by the loss of market share and margin due to increased competition of new primary dealers. Since in our data set we have an identifier of whether a primary dealer is a bank PD or not, we use the heterogeneity among the primary dealers to evaluate the differential impact of entry. We interact the bank PD dummy with the entry dummy to evaluate the impact of this heterogenous impact.

Third, we use a structural estimation of bidding behavior in multi-unit auctions to estimate the distribution of unobserved valuations of the primary dealers from treasury bond auctions (Hortacsu et al (2010, 2019)). Based on these estimates of valuations and actual bidding behavior for each bidder, we can find the actual bid-shading by each primary dealers for each auction. Since these are based on a structural model of bidding, they are not subject to any unobserved bidder specific confounding effects. We employ the underlying (structural) bid-shading measures (as perceived by the bidder ex-ante while bidding), to evaluate the impact of new primary dealer's entry.

4.2 Structural Estimation of Entry and Bidding Behavior

While the difference in difference methodology is useful in identifying the impact of entry on liquidity and related variables; a few underlying structural parameters are of central interest which can only be identified and estimated via structural estimation. For example, the underlying distribution of private valuations is an important set of variables which is useful to conduct various counterfactual policies. We follow Gupta and Sundaram (2015) and Hortacsu et al (2010) in estimating the distribution of valuations of bidders in the primary market based on observed data on bidding behavior. These distributions can then be used to evaluate counterfactual policy questions about the impact of competition on liquidity and other market wide impacts.

5 Reduced form Evidence

5.1 Descriptive Statistics on the Impact of Entry

We report here some preliminary descriptive statistics on the effect of entry of new primary dealers on the primary and secondary market liquidity and trading behavior. We use volatility of the trade prices and volume of trade as a measure of pre auction day secondary market liquidity. For the primary market, we report the underwriting commission of the G-Sec as charged by the primary dealers to RBI to evaluate the impact of competition on underwriting. As can be seen from table 1, the liquidity in the secondary market improved substantially in terms of lower volatility and higher volume of trades following the entry of Goldman Sachs. The underwriting commission has gone down substantially, for example after the entry of Goldman Sachs, the underwriting commission has gone down from 0.97 paise per hundred rupees of the government bond to 0.89 paise. The average total number of bidders in an auction in the primary market also saw a modest increase from 47 to 51. Both traded volume and the number of trades post auction goes up and post auction volatility of trade prices go down significantly after Goldman entry, perhaps signifying higher information production and liquidity provision in the primary market. Similar movements were noted for the entry of other primary dealers.

INSERT TABLE 4 ABOUT HERE

We first report a few relevant important summary statistics of the primary bidding behavior: number of bids per bidder, variance of bids per bidder, the average value weighted price submitted by each bidder, total tender quantity submitted by a bidder as a proportion of the issue size and the proportion of the tender quantity that a bidder won. The number of bids per bidder is the number of bid-quantity pair submitted by each individual bidder (number of bid-quantiy pairs on the individual primary dealer's demand curve) in a particular auction. The variance of bids per bidder is the variance of the prices submitted by an individual bidder in an auction. Both number of bids and bid variance can be affected by competition. Both higher bid variance and higher number of bids are equivalent to flattening of the individual demand curve submitted by the bidder. Ceteris paribus, bidders are expected to flatten their demand curve in lieu of increased competition. However, both number of bids and bid variance can also be affected by the degree of asymmetric information. It is expected that if the bidders have high degree of asymmetric information they would submit more number of bids to spread the risk. If the degree of asymmetric information is high, the bidder is also expected to increase the variance of their demand curve.

We find that the value weighted price submitted by each bidder goes up from 98.4 to 98.7 post Goldman entry. Bidders on an average bid for about 7% of the issue size (median being about 3%) pre-Goldman entry, which goes up to about 7.3% of the issue size (median being 4%). Bidders win about 20% of their bids pre-Goldman entry, which goes up to about 33% post Goldman entry. The difference between the mean and the median of the bid proportion and win proportion suggests that there is a significant size effect among bidders. This is expected as primary dealers are more likely to bid and win in higher proportion than smaller bidders. We also find that the number of bids submitted by the bidder as well as the variance of bids per bidder goes down significantly after the Goldman entry as reported in the table below. Similar results are observed in response to the entry of other primary dealers. This perhaps signifies that the reduction in asymmetric information effect dominates the improvement of competition effect post entry of new primary dealer.

One immediate consequence of market power of primary dealers is reflected as the lowered bid relative to his perceived marginal valuation (willingness to pay) in the primary market auction of government securities. Higher market power of the bidder will result in higher discrepancy from his marginal value and actual bid submitted. We follow Nyborg and Sundaresan (2002) in defining an ex-post reduced form measure of individual bidder's market power as bid shading in the primary market. Specifically, ex-post bid-shading[5] is defined as the

$$\text{Bid Shading}=1-(\text{Value weighted bid submitted by dealer/Post Auction Value Weighted Price}) \tag{2}$$

We report the summary statistics of ex-post bid-shading by primary dealers around the entry by new primary dealers. We report the bid shading by the primary dealers pre and post entry of the respective primary dealer in that particular year. The bid shading by the primary dealer has substantially gone down on an average for that particular year before and after the entry.

[5] We shall define and explore the ex-ante bid-shading in the structural model in the next section.

INSERT TABLE 5 ABOUT HERE

5.2 Reduce Form Evidence: Value Weighted Bids

We first analyze the impact of entry of new primary dealer on the value weighted bid price submitted by bidders in a regression setting. We regress the quantity weighted bid submitted by every bidder normalized by the pre auction secondary market prices (VWBid_Norm) on various auction, bidder and market characteristics and the dummy variables for Axis Bank, Goldman and Nomura entry. We use log of the notified amount, pre auction (one day before) market volatility of the issue in the secondary market and logarithm of pre auction traded volume as auction specific covariates. We use a total amount tendered as a proportion of the notified amount as a control for bidder size (Bidder PropQ). A dummy equal to 1 if the bidder is a primary dealer and 0 otherwise control for bidder type (PD Dummy). Finally a dummy equal to 1 for post entry period of a new primary dealer and zero otherwise controls for the impact of entry. Hence Goldman Dummy takes a value of 1 for the post Goldman entry period and 0 otherwise, Nomura Dummy takes a value of 1 for the post Nomura entry period and 0 otherwise. Axis Dummy is defined accordingly..

The results are reported in table below. We find that all bidders bid significantly higher prices in the auction post entry period of new primary dealers. Interestingly, primary dealers who otherwise bid lower relative to other bidders (as signified by a negative sign of PD Dummy), bids higher post entry (as represented by the interaction of the dummy of the primary dealer dummy with respective primary dealer dummy). These results are consistent subject to controlling for bidder tender size effect and other controls. These results signifies an increase in competition in the treasury auctions, especially among the primary dealers post Goldman entry.

INSERT TABLE 6 ABOUT HERE

5.3 Reduced Form Evidence: Bid Shading

We now turn to the regression analysis of the ex-post bid-shading by the primary dealers. We regress the ex-post bid-shading by the primary dealers. The dependent variable is the bid-shading as defined in equation 2. The independent variables in the baseline regression are the pre-auction trade volume (in billions of INR) (Pre Auction Volume), pre auction normalized volatility as measured by the standard deviation of the traded prices normalized by the pre auction traded volume (Pre Auction Volatility), log of normalized notified amount (normalized by pre auction trade volume) (Auction Supply), the underwriting commission rate as measured expressed in basis points per INR

100 insured (Underwriting Commission), bank primary dealer dummy (equals 1) if the bidders is a bank primary dealer (BKPD Dummy) and Axis Bank, Goldman (equals 1 if the auction held after Goldman entered as a primary dealer for Goldman dummy, other defined accordingly) and Nomura dummy . Since bidder's size may also affect its own bid not-only because the bidder has market power but because of bidder's higher demand, following Hortacsu et al (2018), we also control for bidder's share of the total tender size as a proxy for bidder's size.

The result is given in the first column of table 7 below. The primary coefficient of interest is the coefficient of the respective primary dealer entry dummy (Goldman, Nomura, Axis Dummy). For the case of Goldman Dummy, that coefficient is significantly negative -0.37, signifying that the primary dealers on an average reduce their bid-shading by about 37 basis points after the Goldman entry. The coefficient of other variables also have desired signs and economically significant. For example, increased auction supply leads to an increase in the bid-shading since primary dealers expect a higher suppression of the cut-off price. Higher underwriting commission represents higher costs of insurance of the underlying issue and is a measure of (worse) quality of the issue. Bidder significantly increase their bid shading to seek compensation for the associated risk. As mentioned earlier bank primary dealers can hold part of the amount won during the auction on their balance sheet to satisfy the regulatory reserve ratio (Statutory Liquidity Ratio); and hence have a relaxed budget constraint. Bank primary dealers therefore shade their bid less than the standalone primary dealers who donot have such advantage.

To address the potential issue of endogeneity and confounders or omitted issue characteristics, we employ a second empirical approach in table 7. As argued earlier the Indian treasury bond market has presence of two different types of primary dealers: bank PD and standalone PD. The bank PDs can hold the underlying security won in the auction on their balance sheet to meet their statutory liquidity ratio with the central bank (RBI). This heterogeneity leaves the bank PDs less concerned about the flipping value of the underlying security. Since the higher information production benefit due to increased entry is less relevant for the bank PDs, the should behave differently relative to the standalone PDs. We estimate this impact through the interaction of the bank PD dummy with the respective entry dummy. For example, the Goldman Dummy interacted with the bank PD dummy measures the relative change in the bid shading by the bank PDs (relative to standalone PDs) after the Goldman entry.

The results are given in table 7 below. As expected, we find that the ex-post bid-shading goes up for the successful auctions held on the devolved week. For example, after the Goldman Sachs entry, primary dealers shade their bids by about 38 basis points more for the successful auctions held on the devolved week. The interaction of the dummy with Goldman is significantly negative.

According to this results primary dealers shade their bids 27 basis point less for the successful auction held on a devolved week post Goldman entry. This suggests that the entry of Goldman improves the liquidity provision by the primary dealer in days when a bad shock happens. Similar results are seen after the entry of other primary dealers.

Overall the liquidity provision by the primary dealers in the primary market of treasury securities as measured by the (negative of) ex-post bid-shading goes up after the entry of new primary dealers.

INSERT TABLE 7 ABOUT HERE

6 A Structural Model of Bidding in the Primary Market

In this section we present a model of the bidding behavior in the treasury auction. The aim of this section is to identify and estimate the distribution of valuations privately observed by bidders. These valuations will be used as the marginal willingness to pay (MWP) for the bidders. We follow Hortacsu and McAdams (2010) and Hortacsu and Kastl (2012) in modeling the multiunit treasury auction.

A building block of modeling the bidding behavior is the nature of valuation of the bidders. It is practical to model the treasury auctions as common value auctions as the underlying security is a treasury bond or bills whose valuation is most likely common value in nature. However, as shown by Nyborg and Strebulaev (2004), bidders in treasury securities behave as if they have different valuations even if the underlying security is common value in nature. Nyborg and Strebulaev (2004) attribute this to the role of pre-auction inventory and the possibility of short squeezes in the secondary market following a treasury auction. We model the treasury auction as a conditionally independent private value auction; conditioned on the pre auction values in the secondary market and other relevant public information available prior to the auction.

We follow the modified version of the Wilson (1979) share auction model by Hortacsu and Kastl (2012) in modelling the bidding behavior. Here are a few necessary attributes of the model and notations.

Auctions: There are T auctions. Each auction $t = 1, .., T$ is either a discriminatory or uniform price auction of Q_t arbitrarily divisible units. We restrict analysis here for the discriminatory auctions. The analysis for uniform price auctions follow similar approach and leads to a different first order condition and will be analyzed later.

Bidders: There are N_t bidders in auction t. Bidders in each auction are conditionally symmetric and risk neutral with independent private values; conditioned on the observable characteristics and pre-auction values X.

Valuations: Bidders signals $\theta_1, \theta_2, .., \theta_N$ are drawn from a common support $[0,1]^M$ according to an joint distribution $F(\theta_1, \theta_2, .., \theta_N|X)$ with density function $f(.)$, where X is public observable set of variables prior to the auction. Signals are distributed independently (conditional on X) across bidders and across different auctions. The marginal valuation function $v(q, \theta_i)$, is increasing in θ and weakly decreasing in q, where q is the quantity won by bidder. For notational convenience, henceforth, we drop the index t and conditional variable X.

The gross utility for bidder i with signal θ_i, from bidding in the auction is given by $V(q, \theta_i) = \int_0^q v(u, \theta_i)$.

Action Sets: Each bidder choose an action tuple (b_i, q_i, K), where $b_i(.)$ is a schedule of non-decreasing price and $q_i(.)$ is the corresponding cumulative quantity of dimension K_i, where K_i is a finite natural number. The strategy set is therefore consistent with the rules governing the treasury auctions, where bidders are allowed to submit step functions with K steps. A bid point (b_{ik}, q_{ik}) for bidder i together with the preceding bidpoint (b_{ik-1}, q_{ik-1}) thus specify the marginal quantity $(q_{ik} - q_{ik-1})$, that bidder i is bidding b_{ik}.

Expected payoff: All bidders use strategies $\{y(.|\theta_j)_{j\neq i}\}$, and bidder i follow a strategy $y(.|\theta_i)$. The vector of strategies $y(.|\theta) = [y(.|\theta_1), .., y(.|\theta_N)]$ denotes the vector of submitted bid schedules. Let P^c be the market cleaning price. Let $Q_i^c(\theta, y(.|\theta))$ denote the quantity that bidder i obtains given state θ and bidders are using a strategy $y(.|\theta)$. Bidders $i's$ interim expected payoffs are given by

$$\Pi_i(\theta_i) = E_{\theta_{-i}} \int_0^{Q_i^c(\theta, y(.|\theta))} v(u, \theta_i)du - \sum_{k=1}^{K_i} 1(Q_i^c(\theta, y(.|\theta)) \geq q_{ik})(q_{ik} - q_{ik-1})b_{ik} \tag{3}$$
$$- \sum_{k=1}^{K_i} 1(q_{ik} \geq Q_i^c(\theta, y(.|\theta)) > q_{ik-1})(Q_i^c(\theta, y(.|\theta) - q_{ik-1})b_{ik}$$

where the first term is the gross utility of the bidder, the second term is what the bidder pays for quantities on which the bidder is not rationed, and the last term is what the bidder pays for quantities on which he is rationed. $Q_i^c(Q, \theta, y(.|\theta)$ is the market clearing quantity bidder i obtains if the bidder's private information is θ_i and the quantity auctioned is Q.

6.1 Equilibrium

We compute Bayesian Nash equilibrium (BNE) to find the equilibrium bidding strategies of bidders. In such an equilibrium, all players maximize their expected utility in 3 by choosing their respective bid function $y_i[.]$. The vector of the bid functions maximizing 3 will constitute an equilibrium strategy $y(.|\theta)$.

Under the assumptions described above, Kastl (2012) showed that the necessary condition for a pure strategy BNE equilibrium in uniform price auction can be characterized by the following necessary condition

$$v(q_{ik},\theta_i) = E(P^c|b_{ik} > P^c > b_{ik}) + \frac{q_{ik}}{\Pr(b_{ik} > P^c > b_{ik+1}|\theta_i)} \frac{\delta E(P^C; b_{ik} \geq P^c \geq b_{ik+1}|\theta_i)}{\delta q_{ik}} \tag{4}$$

and at the last step $K_i : b_{iK_i} = v(\overline{q_i},\theta_i)$, where $\overline{q_i} = \sup_{\theta_{-1}} Q_i^c(\theta_i, \theta_{-i}, y(.|\theta))$, where P^c is the equilibrium market clearing price. In an uniform price auction all bidders pay this price for the bids above P^c. This is a major source of uncertainty in an auction.

The necessary condition for equilibrium described above provides a mapping from the observed distribution of bids (in the right hand side), to the object of interest: the distribution of privately observed valuations $v(.)$ (of the left hand side). The above equation is the necessary condition for each point of the bid distribution.

Comparing equation 1 with the equation 4, we note that the bid shading component is represented by the second term $\frac{q_{ik}}{\Pr(b_{ik}>P^c>b_{ik+1}|\theta_i)} \frac{\delta E(P^C; b_{ik} \geq P^c \geq b_{ik+1}|\theta_i)}{\delta q_{ik}}$ in the right hand side of equation 4, and is a measure of market power for individual bidder. Writing this expression in terms of the bid submitted we find that bidders will shade their bids depending on their market power.

$$\underbrace{E(P^c|b_{ik} > P^c > b_{ik})}_{Bid} = \underbrace{v(q_{ik},\theta_i)}_{WTP} - \underbrace{\frac{q_{ik}}{\Pr(b_{ik} > P^c > b_{ik+1}|\theta_i)} \frac{\delta E(P^C; b_{ik} \geq P^c \geq b_{ik+1}|\theta_i)}{\delta q_{ik}}}_{Market \text{ Power (Bid-Shading)}} \tag{5}$$

The extent of market power as expressed by the second term, in equilibrium therefore depends on the expectation of the distribution of the equilibrium market clearing price P^c, conditional on the expectation of individual bidder's valuations. This is effectively the elasticity of the residual supply function for each bidder. An estimate of this term is therefore crucial in identifying the impact of competition. This above equation is akin to the standard market power definition in industrial organization literature, where the market power θ is related to the actual price submitted through the equilibrium pricing condition $p = mc + \theta p'(q)q$ (Breshnahan (1989), Ellison (1994)). For auctions, the goal is to estimate the last term in equation4 as a measure of market power across bidders and auctions.

Our objective in this paper is to analyze how this factor differs across periods before and after Goldman entry. We also analyze the relative difference of this term across different types of bidders; primary dealers vs. other bidders, bank primary dealers vs. stand-alone primary dealers. This helps us address the issue of heterogeneity and its underlying source across different types of financial intermediaries and its impact on asset prices (He and Krishnamurthy (2018)). The market participants can be heterogeneous because they may have different information set and hence will have differential price impact.

The equilibrium condition as in equation4 can be estimated for each bid -quantity pair for each bidder. We shall use a quantity weighted measure to define the average ex-ante bid-shading by each bidder as $BS(\theta_i) = \frac{\sum_{k=1}^{K} qk[v_i(q_k,\theta_i) - E[P^C|b_k > P^C > b_{k+1}, \theta_i)}{\sum_{k=1}^{K} q_k}$. This is an ex-ante measure of how the bidders expected inverse elasticity of the residual supply curve behave on an average. Primary dealers may be bidding lower for a security not because they have lower valuation but they have higher market power as measured by this elasticity.

The distribution of the market clearing price can be different for bidders who are primary dealers vs. other who may be submitting their bids through the primary dealers (indirect bidders) or bidders who are not a primary dealers but submitting a direct bid (direct bidders). In the Indian treasury auction system, various banks, insurance and other financial institutions who are not a primary dealers also submits bids directly in the treasury auction. We refer the reader to Hortacsu and Kastl (2012) and Hortacsu et al (2018) for a discussion and implications of different types of bidders on the bidding behavior.

Estimation of the marginal valuations

We use the equilibrium condition described above in equation 4 to identify and estimate the distribution of the unobserved valuations of the bidders. As shown in Hortacsu and McAdams (2010), Hortacsu et al (2018) and Kastl (2011), the above equilibrium is monotonic and hence if one can non-paratemtrically estimate the right hand side of equation 4 from the observed distribution of bids, we can estimate the unobserved distribution of marginal valuation $v_i(.)$ of bidders. This is the structural estimate of the marginal value of wealth as described an important component for the asset prices by He et al (2017).

6.2 Data Requirement for Structural Estimation

As described earlier we have access to the individual demand curves (bid quantity pairs) submitted by each bidder in an auction. We have therefore access to $\{B_{1t}, ..., B_{Nt}, Q_t, X_t\}$, where for each auction t of T auctions; $B_{1t}, .., B_{Nt}$ are the set of bid functions submitted by each bidder, Q_t is the auction supply and X_t are some auction specific covariates. Each bidder submits a step function of bids; $\{(q_{itk}, b_{itk})\}_{k=1}^{K_{it}}$, where K_{it} is the number of steps bidder i submits in auction t.

As described in the data section, there are three major types of bidders in the Indian treasury auctions: standalone primary dealers, bank primary dealers and other bidders. Each such groups of bidders may bid differently due to various funding and other institutional reasons. This makes the bidders inherently heterogenous ex-ante and their bid function should be different across groups. For simplicity of notations we first describe the equilibrium and estimation strategy for a homogenous sets of bidders. This will be extended in later sections to incorporate the heterogeneity of bidders.

The supply of the treasury security Q_t is generally deterministic and announced much earlier than the auction date[6]. This is typically the case for treasury bills. However the Indian treasury auction also has an additional unique feature of devolvement for the government bonds. If the auctioneer (the Reserve Bank of India (RBI)) reserve the right to (partially) devolve the amount auctioned after observing the distribution of bids (Gupta et al (2020)). In case of devolvement the auctioneer sets a different quantity, which is lower than the preannounced supply of the underlying security to generate higher auction cut-off price (lower cut-off yield) from the auction. The remaining amount is distributed among the primary dealers (at the auction cut-off yield) based on a pre determined formula. The amount that each primary dealers may receive in case of such a devolvement depends on the auction underwriting process, and are known to each primary dealers before the auction begins. This amount therefore acts like a pre-auction off the balance sheet inventory (which becomes on the balance sheet inventory in case of devolvement). We treat this as bidder specific covariate Z_{it} for each auction. Clearly, this pre-auction inventory may have a strong influence on the bidding behavior through its impact on bidder's funding and liquidity costs. The variable Z_{it} therefore acts like a conditioning variable for the distribution of bidders private signals.

6.3 Estimation

We follow the resampling procedure of Hortacsu and McAdams (2010) and Hortacsu and Kastl (2012) and Hortacsu et al (218), in estimation of the marginal valuation. For notional simplicity, we first suppress the auction specific covariate X_t and bidder specific covariate Z_{it} while describing the estimation algorithm. As will be described later, this variables will appear as a conditional variables in the bid function for each bidder when we first describe the estimation algorithm. These variable will be accounted for the estimation process.

One important constituent of the estimation of the distribution of private valuation, as described in equation 4, is the distribution of the market clearing price P^c. The distribution of P^c, is essential to get an estimate of $\Pr(b_{ik+1} \geq P^c|\theta_i)$ which in turn will give us an estimate of v_i in equation 4 from the observed distribution of bids.

Following Hortacsu and McAdams (2010) and Hortacsu and Kastl (2012), we follow the following

[6]Give a RBI notification example.

resampling procedure to generate the distribution of the market clearing price.

6.3.1 Estimation Algorithm

1.Fix a bidder and his bid function $y(p|\theta_i)$ in auction t.

2. Draw $N-1$ bid functions from all bids with replacement and compute the residual supply function $Q - \sum_{j=1}^{N-1} y(p|\theta_j)$.

3.Compute the market clearing price P^c given bidder $i's$ bid function $y(p|\theta_i)$ and the quantity won by the bidder for each step of his bid function q_{ik}.

4. Repeat steps 1 through 3 S times. This generates a distribution of market clearing prices for each bid function $y(p|\theta_i)$. Hortacsu and McAdams(2010), and Hortacsu and Kastl (2012) have shown that this is a consistent estimate of the numerator and denominator of the fraction on the right hand side of equation 4.

We perform steps 1 through 4 for each bidder and every auction. Cassola, Hortacsu and Kastl (2013) has shown that the estimator is consistent if the number of bidders is large. This implies that we can just use one auction at a time to follow the resampling procedure and estimate the probability of the market clearing price. This is important as the estimation is not affected by any other unobservable characteristics. This helps us avoid the possibility of changing economic environment and unobserved auction heterogeneity affecting our estimation procedure. Since the period of our study overlaps with a changing economic environment coming out of the great recession of 2008, focussing on individual auctions bid to get a consistent estimate of the valuation helps us overcome any issue related to other unobserved heterogeneity affecting the bid functions and hence our estimates.

Since the primary dealers in our system also participate in the underwriting of the underlying issue, which may affect their budget constraint, they are expected to be different than the rest of the bidders. Since we know who is a primary dealer in our dataset, following Hortacsu et al (2018), we modify the resampling procedure described above slightly to incorporate this asymmetry amongst the bidders. Suppose there are M total bids and N_P of those bids are from the primary dealers. For each step of resampling, fixing a primary dealer who submitted n bids, we draw $N_p - n$ bids from the bids of the primary dealers and $M - N_p$ bids from other bidders. We then add the primary dealers (n) bids to this set to crate a new demand curve to get a simulated market clearing price. We then follow this procedure for 5000 types for each primary dealers to estimate the distribution of the market clearing price. This modified procedure helps preserve the asymmetry amongst the bidders in our estimated value of the market clearing price. We use this modified resampling procedure to estimate the distribution of the unobserved valuations for each bidder.

It is important to note here that we run this procedure auction by auction. Unobserved heterogeneity across auctions and its implications on valuations is a big concern. Pooling of bidding data across auctions may generate a very different demand structure which may in turn give us a biased estimate of the market clearing price and hence the distribution of unobserved valuations. Since we run this procedure auction by auction we mitigate the changing market structure issues especially during the post great recessions period. Cassola, Hortacsu and Kastl (2013) showed that such a procedure gives a consistent estimate.

6.4 Structural Estimation Results

For every auction and every bidder, we use $S = 5000$, resamples to estimate the distribution of the market clearing price. As we described earlier, the resampling procedure involves drawing residual supply curves for each bidder in an auction by fixing the bidder's demand curve and then resampling from other bidders' bids to generate a market clearing price. In the figure 1A below we fix bidder 5 in an auction and generate 100 residual supply curves for the bidder. The $X - axis$ represents the price bid for the underlying security and the $Y - axis$ represents the cumulative demand quantity. The probability of winning for bidder 5 for his bids, lies in a narrow range. This is even clearer in the following figure 1B, which shows the distribution of stop out price has a positive density over 6 basis points.

INSERT FIGURE 1A AND FIGURE 1B ABOUT HERE

The marginal valuation of the bidder as described in the right hand side of equation 4 and his submitted bid function is described in the following figure. We calculate the standard deviation of this marginal valuation of the bidder using a bootstrap sample of 100 estimates generated by following the resampling procedure described above.

INSERT FIGURE 2 ABOUT HERE

We report the kernel density function of bidders' marginal valuations (as depicted in the left hand side of equation 4), in the following figure. The figure shows the estimated density function of the quantity weighted valuations in two respective periods (pre Goldman entry and post Goldman entry). We find a sharp difference in the marginal valuations for two different periods.

INSERT FIGURE3 ABOUT HERE

6.5 Impact of Entry on Ex-ante Bid-Shading

As discussed earlier, The equilibrium impact of market power of each bidder can be represented by the term $[\widehat{v}(q_{ik}) - b_{ik}]$ for each k^{th} step of his bid, as derived in equation 4. This term is the difference from the marginal willingness to pay and the actual bid submitted by bidder for each of the k^{th} step of his bids. This terms depends on the level of competition in the market as well as the asymmetric information. This is the magnitude of ex-ante bid shading.

To quantify the effect of entry of new primary dealers on ex-ante bid-shading (bidders's surplus) we use two measures as used in Elsinger et al (2019); the ex-post surplus and the interim surplus. The ex-post surplus is defined as the quantity weighted amount that each bidder shades his winning bids as defined in the first order condition of optimal bidding in equation 4, this is given by:

$$S_t = \sum_{i=1}^{N_t} \sum_{k=1}^{K_t} [1(Q_i^c > q_{ik})(q_{ik} - q_{ik-1}) +$$
$$1(q_{ik} \geq Q_i^c(\theta, y(.|\theta)) > q_{ik-1})(Q_i^c(\theta, y(.|\theta)) - q_{ik-1})].(\widehat{v}(q_{ik}) - b_{ik}) \tag{6}$$

where Q_i^c is the quantity won by bidder i and $\widehat{v}(q_{ik})$ is the estimate of the marginal valuation of the bidder as obtained in equation 4 for the valuation at quantity step q_{ik} in the auction.

We report the summary statistics of ex-ante bid shading results in table below for both before and after Axis Bank, Goldman Sachs and Nomura entry as primary dealers in the treasury auction. The ex-post surplus for primary dealers has fallen substantially after the entry of Goldman Sachs, signifying a benefit of the competition in the primary market.

INSERT TABLE 8 ABOUT HERE

We then regress the ex-ante bid-shading on various market characteristics and a dummy for Goldman entry to evaluate the impact of Goldman entry on the primary dealers bidding behavior. The results are given in table 9 below. We find that the bid shading by primary dealer goes down by approximately 5 basis points after Goldman entry.

INSERT TABLE 9 ABOUT HERE

6.6 Post Auction Liquidity and Auction Market Power

We next turn to the impact of Goldman entry on the behavior of post auction liquidity in the secondary market. We use the standard deviation of the value weighted secondary market prices day after the auction (volatility) as a measure of the post auction secondary market liquidity. Higher liquidity should lead to a lower volatility in the secondary market. According to Pasquariello and Vega (2009) the endowment shocks generated by the primary market auction works as the primary channel through which it impacts the secondary market liquidity. The channel works in the following way: market makers generally hedge against the adverse selection created by more informed speculators by lowering the liquidity of a security (Kyle (1985)). For a recently issued auction, part of the speculators' position is coming from an exogenous endowment shock received in the primary market. This in turn should lower the adverse selection component of the orders for the recently concluded auctions. The market maker therefore demands less premium and provides more liquidity in the secondary market.

In our case the impact of new primary dealer's entry affects the number of speculators through an increase in the number of primary dealers. Presence of higher competition amongst speculators in turn improves the informativeness of the order flow in the secondary market which in turn should improve liquidity. Presence of new primary dealers like Goldman and Nomura etc., who has experience in operating in mature markets, should also generate more information from the primary market (auction) outcome which in turn should also improve liquidity in the secondary market. We find results consistent with this line of argument. In the table below we run a regression of the post auction liquidity on the primary dealer entry dummy and various other controls. We find that the liquidity goes up (volatility goes down) significantly after entry of new primary dealers. Moreover the proportion of auctioned security won by the primary dealers has a significant negative (positive) effect on volatility (liquidity). This is consistent with Pasquariello and Vega (2009), as primary dealers are expected to act as speculators in the post auction secondary market. Higher amount won buy them in the auction is equivalent to a larger shock in their endowment and hence less adverse selection in the post auction secondary market. For example, based on column one, one standard deviation (0.1585) increase in the proportion of auction supply won by the primary dealer in the primary market, leads to about 4.8 basis point (0.1585 x0.305) increase in liquidity.

The structural estimate of the competitiveness as measured as the log of bid shading by the primary dealers has a significant negative (positive) effect on liquidity (volatility). Lower competitiveness by the primary dealers leads to lower liquidity in the post auction secondary market. For example, for the case of Goldman entry, one standard deviation (4.98) increase in the market power of the primary dealer in the primary market, leads to about 4 basis point (4.98 x0.00847) lower liquidity.

INSERT TABLE 10 ABOUT HERE

6.7 Heterogeneity of Market Power and Impact on Prices

He and Krishnamurthy (2018) listed the analysis of the heterogeneity of financial intermediaries and its impact on asset prices as an important future direction of research. In this section, we analyze the heterogeneity of market power of the financial intermediaries and its impact on the treasury securities prices in both primary and post- auction secondary market.

As discussed earlier the primary market for treasury auctions in India has two major groups of participants: primary dealers and other bidders. The primary dealers are in turn are categorized into two broad groups: bank primary dealers and stand-alone primary dealers. The bank primary dealers has an added advantage of using part of the amount won in the treasury auctions towards meeting their mandatory liquidity ratio (SLR) requirements with the central bank (RBI). This makes their budget constraint relatively more flexible compared to the stand alone primary dealers. All primary dealers are required to participate in the auction process and provide the underwriting support against potential devolvement as described earlier. The bank primary dealer thus have an advantage through their relaxed budget constraint which introduces heterogeneity among primary dealers. Fleming and Rosenberg (2007) describes that treasury dealers inventory positions increase during the auction week which are not often hedged against futures. They found that dealers are generally compensated for the risk associated with their inventory changes in subsequent weeks in terms of increased prices. This should affect the incentives of the bank primary dealers to flip the auction owned securities and potentially affect the customer base relative to the stand-alone primary dealers.

According to Fleming (2008), primary dealers consolidate advance customer orders and act as a broker for customer orders at auction. They also keep a large part of the inventory on their own account. Fleming(2007) finds that treasury dealers acquire on an average 71% of the issues on their own accounts. Primary dealers also makes markets in the secondary market. Fleming (2008) argued that although their is little asymmetric information from purchases at auction, there is potential of significant asymmetric information in trades with customers. Hortacsu and Kastl (2012) analyzed the role of customer orders in the bidding behavior of primary dealers.

The source of heterogeneity among primary dealers in the Indian treasury auction system therefore originates from two sources: institutional setting which makes the bank primary dealers different from stand alone primary dealers and the behavior and outcome of the auction process as manifested in the changing inventory position of the dealers.

Several authors showed that the order flow of the US treasury dealers in informative for post auction secondary market prices (Fleming (2003), Brandt and Kavajecz(2004), Green (2007) and Pasquariello and Vega (2007)). We explore the impact of heterogeneity among the primary dealers on the secondary market prices and liquidity.

We normalize the post auction secondary market prices, traded volume and volatility by the pre-auction price, volume and volatility respectively and use these as the dependent variables in an OLS regression. The independent variables are the average structural estimates of market power of the stand alone primary dealer and bank primary dealers, the average amount won (as a proportion of the notified amount) by bank and standalone primary dealers. We also control for pre auction volume, volatility and the normalized notified amount in the auction (auction supply).

Table 11 below describes the results. We use the results of the last column of the table to describe the impact of market power and dealer heterogeneity on secondary market prices. The dependent variables is the post auction (one day after auction) secondary market prices normalized by the pre auction secondary market prices. We use the ratio of the structural estimate of the average value weighted bid shading by stand alone primary dealer to that of the bank primary dealer as a measure of the degree of heterogeneity of primary dealers in auction. Note that these structural estimates are based on the estimation of the equilibrium bidding equation of equation 4.

We find that the relative market power of the stand alone primary dealers has a significant positive impact on the post auction (normalized) prices. This is consistent with Nyborg and Straulaev(2004)'s theory of impact of short squeezes and market power on the post auction secondary market prices. One standard deviation (22.14) increase in the ratio of the structural estimate of market power of the stand alone primary dealer (Stand Alone PD Bid Shading) relative to the bank primary dealers leads to about 4.58 basis point increase in the (normalized) post auction secondary market prices. Similarly the amount won by the bank primary dealers has a significant positive impact on post auction normalized prices. A one standard deviation (0.14) increase in the normalized amount won by the bank primary dealers leads to about 11.73 basis point increase in the (normalized) post auction secondary market prices. Since bank primary dealers can hold the amount won in auctions as part of their liquidity ratio requirements, they have less incentive to sell right away in the post auction secondary market. The amount won by bank primary dealers therefore are expected to have impact on short squeezes in the post auction secondary market. To the best of our knowledge, we are the first to empirically examine the link between the structural estimates of market power in the primary market auction to post auction secondary market activities.

INSERT TABLE 11 ABOUT HERE

7 Conclusion

In this paper, we analyzed the role of primary dealer in the liquidity provision in the primary market of treasury securities. We used a unique data set and novel setting to analyze the impact of primary dealers on liquidity through the lens of the entry of a new primary dealer in the Indian treasury securities market. We have shown that the entry of a new primary dealer led to an improvement of liquidity provision by the primary dealers in the primary market. We find a strong predictive power of the structural estimate of the market power of the primary dealers in the primary market with secondary market asset prices and liquidity. We find consistent results in both reduced form regressions as well as in the structural estimation of strategic bidding behavior in treasury auctions. Overall, the structural estimates suggests that the central bank benefited by about INR 20 million per auction due to the improved liquidity provision by the primary dealers.

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Figure 1: Simulation of Residual Supply Curves

Figure 1A shows the residual supply curves from 100 simulations for bidder 5 in auction 7697 given the actual demand curve submitted by bidder 5. Figure 1B shows the distribution of the market clearing prices . The simulation procedure is described in detail in the paper

Figuure 1A: This figure shows 100 randomly drawn residual supply curves and the demand curve of primary dealer 5 in auction 7697

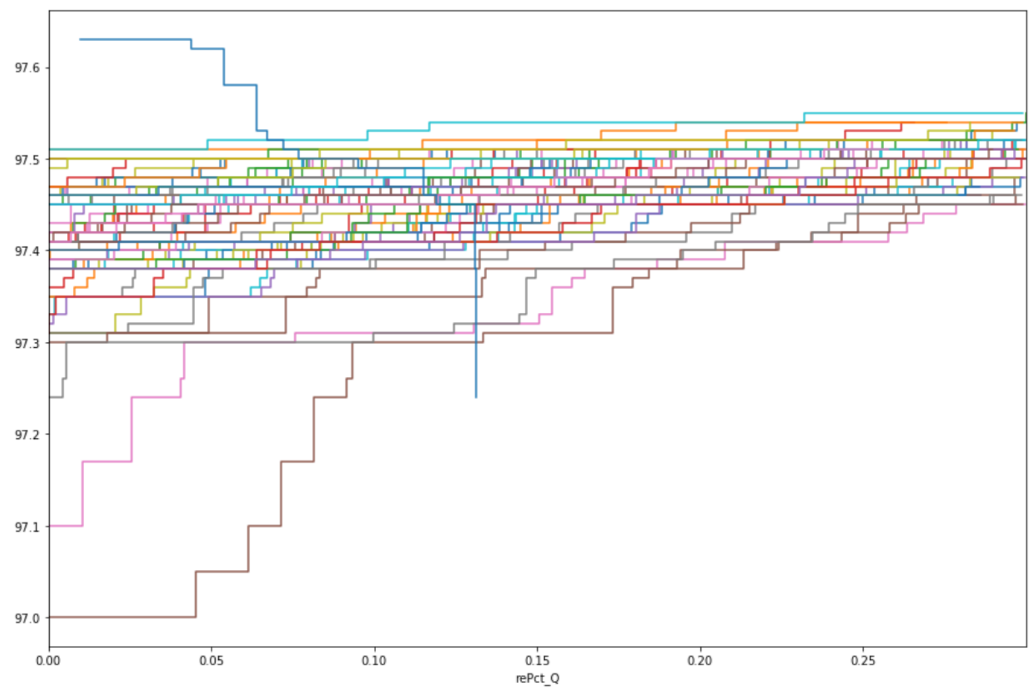

Figure 1B: This figure shows the distribution of the stop-out prices of primary dealer 5 in auction 7697

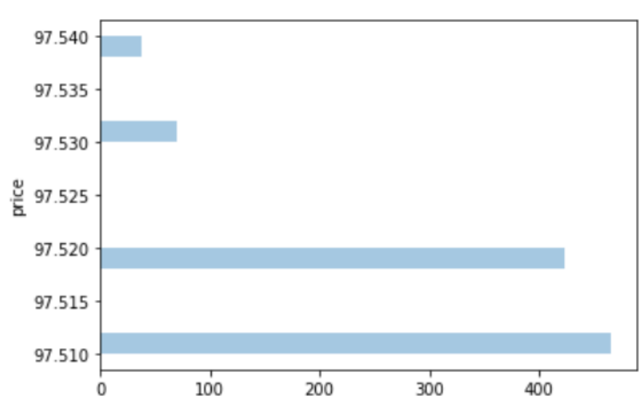

Figure 2: Structural Estimation of Marginal Valuations of Primary Dealers

Figure 2 shows the marginal valuation of primary dealer 5 by the structural estimation procedure described in the paper. In the structural estimation procedure, for each bidder we run 5000 simulated residual supply function to estimate the distribution of the market clearing prices . The simulation procedure is described in detail in the paper

Figure 2: Distribution of Marginal Valuations and Standard Errors of Bidder 5 in Auction 7697

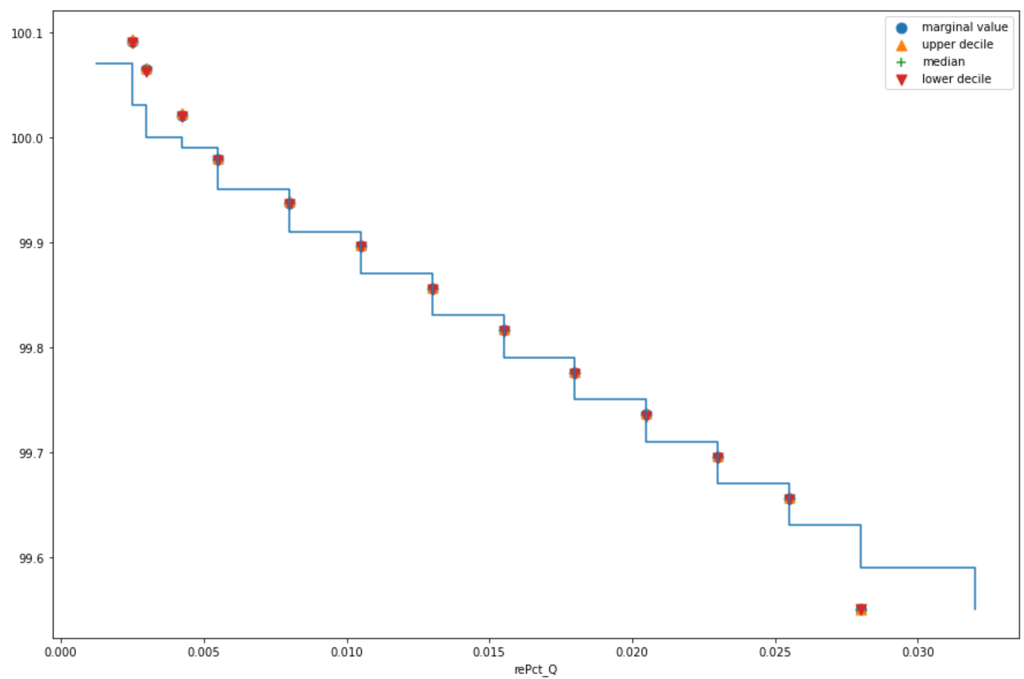

Figure 3: Structural Estimation of Marginal Valuations of Primary Dealers

Figure 3 shows the kernel density of marginal valuation of primary dealers before and after the Goldman entry

Fig 3: Distribution of Marginal Density

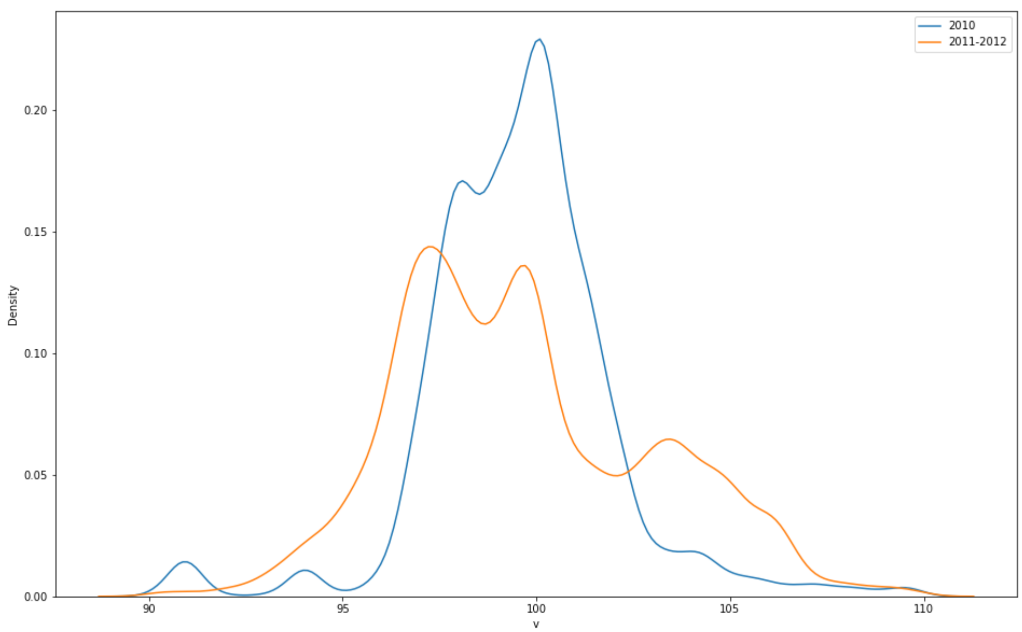

Table 1: Primary Dealers in the Indian Treasury Auction

This table provides the list of primary dealers in the Indian treasury auction system as announced on the Reserve Bank of India Website

Table 1A

Holding Pattern of Treasury Bonds (in %)

Year	Commercial Banks	Standalone PDs	Insurance Co.	Corporates	Others
2008	46.9	0.29	23.2	4.72	24.89
2009	47.25	0.14	22.16	2.99	27.46
2010	47.03	0.11	22.22	1.94	28.7
2011	46.11	0.1	21.08	1.38	31.33
2012	43.86	0.11	18.56	1.14	36.33
2013	44.46	0.11	19.54	0.79	35.1

Source: RBI and Ghose and Raajaram (2015), CCIL

Table 1B

Primary Dealer Statistics

	2008	2009	2010	2011	2012	2013
Share of Standalone PDs in Secondary Market (in %)	16.1	12.8	8.7	16	23.2	17.7
Primary Market Bid Cover Ratio in T-Booonds	1.6	1.34	1.3	1.4	1.3	1.5
Primary Market Successs rate in T-Bonds (in %)	46.2	42.6	42	49.6	47.4	51.1
Return oon Average Assets of Standalone PDs (in %)	2.5	6.6	1.8	1.1	0.8	1.5

(Source : RBI Annual Report on Trends and Progress on Indian Banking)

Table 2: Primary Dealers in Indian Treasury Auction

This table describes different types of primary dealers in Indian Treasury Auction

List of Primary Dealers in India

Standalone Primary Dealers	Bank Primary Dealers
ICICI Securities Primary Dealership	Bank of America
Morgan Stanley India Primary Dealer	Bank Of Baroda
Nomura Fixed Income Securities	Canara Bank
PNB Gilts	Citibank
SBI DFHI	Corporation Bank
STCI Primary Dealer	HDFC Bank
Goldman Sachs (India) Capital Markets	HSBC
	J P Morgan Chase Bank
	Kotak Mahindra Bank
	Standard Chartered Bank
	Axis Bank
	IDBI Bank
	Deutsche Bank

Table 3: Entry of New Primary Dealers

This table describes the dates of entry of new primary dealers in the Indian treasury auction.

Entry Dates of New Primary Dealers		
Primary Dealer	Type	Entry Date
Nomura	Standalone Primary Dealer	September, 2009
Axis Bank	Bank Primary Dealer	April, 2010
Goldman Sachs	Standalone Primary Dealer	April,2011

Source: RBI Annual Reports

Table 4: Summary Statistics of Bidding Behavior

This table describes various auction specific summary statistics before and after the entry of new primary dealers.

	Pre-Goldman Entry			Post Goldman Entry		
Variables	Mean	Median	Std. Dev	Mean	Median	Std. Dev
Duration	12.90	11.00	7.38	14.52	12.00	7.82
Notified Amount (INR Billions)	37.26	40.00	6.80	41.66	40.00	13.08
Pre Auc Std. Dev.	0.00	0.00	0.03	0.00	0.00	0.02
Pre Auc Volume	12.09	6.21	14.54	16.86	5.11	23.50
Post Auc Std. Dev	0.004	0.00	0.03	0.003	0.00	0.02
Post Auc Volume	12.90	4.55	17.79	20.76	6.01	29.18
Post Auc No of Trades	152.90	70.00	177.26	203.16	64.50	274.35
Pre Auc No of Trades	125.69	65.00	142.10	157.43	54.00	205.94
Underwriting Commission	1.39	0.97	1.18	1.72	0.89	2.18
Number of Bidders in Auction	47.20	47.00	15.08	50.80	51.00	11.12

Table 5: Summary Statistics of Bidding Behavior

This table describes the summary statistics of various bidder specific behavior before and after the entry of new primary dealers

	Pre Goldman Entry			Post Goldman Entry		
Variables	Mean	Median	Std. Dev	Mean	Median	Std. Dev
Bid Shading	0.008	0.005	0.016	0.007	0.004	0.011
Bid Shading (%)	0.821	0.481	1.574	0.679	0.427	1.133
Allocated Amount (Prop)	0.027	0.000	0.059	0.024	0.000	0.054
Number of bid by Bidder	4.162	3.000	3.072	3.745	3.000	2.703
Variance of bids by bidder	0.475	0.309	1.215	0.346	0.242	0.408
	Pre Nomura Entry			Post Nomura Entry		
Variables	Mean	Median	Std. Dev	Mean	Median	Std. Dev
Bid Shading	0.021	0.013	0.030	0.007	0.004	0.012
Bid Shading (%)	2.108	1.286	2.964	0.732	0.447	1.204
Allocated Amount (Prop)	0.056	0.030	0.072	0.025	0.000	0.058
Number of bid by Bidder	6.448	5.000	5.672	4.201	3.000	3.040
Variance of bids by bidder	0.849	0.538	1.861	0.400	0.294	0.376
	Pre Axis Bank Entry			Post Axis Bank Entry		
Variables	Mean	Median	Std. Dev	Mean	Median	Std. Dev
Bid Shading	0.017	0.008	0.028	0.006	0.004	0.012
Bid Shading (%)	1.660	0.832	2.785	0.647	0.396	1.169
Allocated Amount (Prop)	0.034	0.000	0.061	0.024	0.000	0.056
Number of bid by Bidder	4.952	4.000	4.489	3.867	3.000	2.829
Variance of bids by bidder	0.770	0.469	1.781	0.354	0.255	0.349

Table 6: Summary Statistics of Value Weighted Bids

This table describes the regression results of value weighted bids by bidders on various variables. The dependent variable is the value weighted bids defined as the value weighted average bid submitted by every bidder relative to pre auction value weighted average price. The independent variable Goldman Dummy takes value 1 for the period after Goldman entered as the primary dealer and takes value 0 otherwise. Auction supply is the log of the notified amount normalized by the pre auction traded volume. Pre auction volatility is the standard deviation of secondary traded prices day before the auction. Pre auction volume is the secondary market traded volume day before the auction. The Bidder PropQ is the amount of the issue demanded by each bidder divided by the auction supply.

Variables	Dependent Variable: Normalized Value Weighted Bid		
Axis Dummy	0.006***		
	-0.0004		
Nomura Dummy		0.0121***	
		-0.000573	
Goldman Dummy			0.000467***
			-0.000106
PD Dummy	-0.00649***	-0.00705***	-0.00432***
	-0.000319	-0.00044	-0.000107
Pre Auction Volatilty	-0.0163***	0.00793*	-0.0117***
	-0.00329	-0.00421	-0.000895
Pre Auction Volume	0.00196***	0.00233***	0.000923***
	-0.000153	-0.00022	-5.31E-05
Auction Supply	0.000965	0.00615***	0.000373**
	-0.00085	-0.00102	-0.000154
Bidder PropQ	0.00637**	0.0114***	0.00243***
	-0.00249	-0.00335	-0.000543
Constant	0.943***	0.805***	0.977***
	-0.0196	-0.0242	-0.00345
Observations	11,506	8,195	13,735
R-squared	0.11	0.14	0.19

** p<0.01, ** p<0.05, * p<0.1

Table 7: Regression Analysis of Ex-Post Bid Shading

This table describes the regression results of ex-post bid-shading on various variables. The dependent variable is the ex-post bid-shading defined as the value weighted average bid submitted by every bidder relative to post auction value weighted average price. The independent variable Goldman Dummy takes value 1 for the period after Goldman entered as the primary dealer and takes value 0 otherwise. BKPD is a dumyy variable which takes value 1 if the bidder (primary dealer) is a bank primary dealer. The underwriting allocation is the amount underwritten by each bidder as a proportion of the notified amount. Auction supply is the log of the notified amount normalized by the pre auction traded volume. Pre auction volatility is the standard deviation of secondary traded prices day before the auction. Pre auction volume is the secondary market traded volume day before the auction. The underwriting commission is the log of the underwriting commission.

VARIABLES	Dependent Var: Ex Post Bid Shading (%)		
BKPD x Goldman Dummy	0.162***		
	-0.0621		
BKPD x Nomura Dummy		0.631***	
		-0.166	
BKPD x Axis Dummy			0.451***
			-0.0978
Goldman Dummy	-0.371***		
	-0.0932		
Nomura Dummy		-0.364**	
		-0.162	
Axis Dummy			-0.310**
			-0.128
BKPD Dummy	-0.151***	-0.695***	-0.466***
	-0.0509	-0.162	-0.0903
Underwritten Amount	0.751***	1.403***	1.332***
	-0.189	-0.279	-0.28
Pre Auction Volume	-0.00165	-0.00480**	-0.00477**
	-0.00118	-0.00192	-0.00191
Pre Auction Volatility	80.78***	84.55***	85.21***
	-29.92	-23.09	-23.41
Auction Supply	0.133***	0.103***	0.103***
	-0.0186	-0.0267	-0.0267
Underwritting Commission	0.0677***	0.0467***	0.0468***
	-0.0156	-0.00426	-0.00405
Constant	0.329***	1.567***	1.447***
	-0.0559	-0.167	-0.15
Year Fixed Effects	Y	Y	Y
Observations	5,490	4,496	4,496
R-squared	0.056	0.251	0.251

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Summary Statistics of Ex-Ante Bid Shading

This table describes the summary statistics of structural estimate of ex-ante bid-shading before and after of entry of new primary dealers.

	Ex-Ante Bid Shading		
	All	Pre Goldman Entry	Post Goldman Entry
Mean	0.111	0.136	0.096
Median	0.021	0.023	0.020
Std. Dev	0.198	0.223	0.180

	Ex-Ante Bid Shading		
	All	Pre Goldman Entry	Post Goldman Entry
Mean	0.167	0.183	0.140
Median	0.072	0.086	0.050
Std. Dev	0.369	0.350	0.400

	Ex-Ante Bid Shading		
	All	Pre Axis Bank Entry	Post Axis Bank Entry
Mean	0.110	0.120	0.108
Median	0.120	0.024	0.037
Std. Dev	0.429	0.382	0.435

Table 9: Regression Analysis of Ex-Ante BidShading

This table describes the regression results of the structural estimate of ex-ante bid-shading on various variables. The dependent variable is the ex-post bid-shading defined as the value weighted average bid submitted by every bidder relative to post auction value weighted average price. The independent variable Goldman Dummy takes value 1 for the period after Goldman entered as the primary dealer and takes value 0 otherwise. BKPD is a dumyy variable which takes value 1 if the bidder (primary dealer) is a bank primary dealer. The underwriting allocation is the amount underwritten by each bidder as a proportion of the notified amount. Auction supply is the log of the notified amount normalized by the pre auction traded volume. Pre auction volatility is the standard deviation of secondary traded prices day before the auction. Pre auction volume is the secondary market traded volume day before the auction. The underwriting commission is the log of the underwriting commission.

VARIABLES	Dependent Variable: Ex Ante Bid Shading		
Goldman Dummy	-0.0258**		
	-0.0113		
Axis Dummy		-0.0156	
		-0.0141	
Nomura Dummy			-0.293***
			-0.0413
Auction Supply	-0.0039	-0.0109***	0.0370***
	-0.00269	-0.00339	-0.00979
Underwriting Commission	-0.0169***	0.0258***	0.00679
	-0.00193	-0.00368	-0.00477
Pre Auction Volatility	-15.76***	-13.52***	-41.74***
	-2.655	-3.23	-4.879
Pre Auction Volume	0.00100***	0.000411	0.000998*
	-0.000279	-0.000351	-0.000549
Constant	0.175***	0.313***	-0.413*
	-0.0636	-0.0789	-0.214
Year Fixed Effects	Y	Y	Y
Observations	4,178	1,869	506
R-squared	0.10	0.11	0.346

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Regression Analysis of Post Auction Liquidity

This table describes the regression results of Post Auction secondary market liquidity on various variables. The dependent variable is the standard deviation of value weighted post auction secondary prices for the day after the treasury auction. The independent variable Goldman Dummy takes value 1 for the period after Goldman entered as the primary dealer and takes value 0 otherwise. Auction supply is the log of the notified amount normalized by the pre auction traded volume. Pre auction volatility is the standard deviation of secondary traded prices day before the auction. The variable PD Win Norm is the amount of the treasury security won by the primary dealers divided by the auction notified amount. Log of PD Bid Shading is the average of the structural estimate of bid shading by the primary dealer in an auction.

VARIABLES	Post Aution Volatility			
Goldman Dummy		-0.0529***	-0.0475***	-0.350**
		-0.0134	-0.0126	-0.156
Goldman Dummy x PD Win Norm				0.296*
				-0.156
Goldman Dummy x Log of PD bidshading				-0.00652**
				-0.00326
Pre Auction Volatility	0.401***	0.384***	0.366**	0.370**
	-0.151	-0.147	-0.145	-0.147
Auction Supply Norm	0.0194**	0.0222***	0.0235***	0.0216***
	-0.00819	-0.00836	-0.008	-0.00772
PD Win Norm			-0.257***	-0.305**
			-0.0898	-0.121
Log of PD bidshading			0.00576***	0.00847***
			-0.00201	-0.00299
Constant	-0.126	-0.13	0.117	0.185
	-0.0909	-0.0898	-0.126	-0.147
Observations	347	347	337	337
R-squared	0.166	0.2	0.277	0.297

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 11: Regression Analysis of Post Auction Secondary Market Prices

This table describes the regression results of Post Auction secondary market prices on various variables. The dependent variable is the value weighted post auction secondary prices for the day after the treasury auction normalized by the pre-auction secondary market prices . The independent variable Auction supply is the log of the notified amount normalized by the pre auction traded volume. Pre auction volatility is the standard deviation of secondary traded prices day before the auction. The variable PD Win Norm is the amount of the treasury security won by the primary dealers divided by the auction notified amount. Log of PD Bid Shading is the average of the structural estimate of bid shading by the primary dealer in an auction. The variable Bank PD takes values 1 if the primary dealer is a bank primary dealer and 0 otherwise.

VARIABLES	Dependent Variable: Post Auc Price Norm		
StandAlone PD Win Norm		-0.00040	-0.00646
		-0.00734	-0.00709
Bank PD Win Norm		0.00280	0.00760**
		-0.00349	-0.00368
Bank PD Bid Shading			-0.00516*
			-0.00294
Stand Alone PD Bid Shading			0.0139***
			-0.00462
Pre Auction Volatility	-0.00032	-0.00199	-0.00239
	-0.00282	-0.00151	-0.00156
Auction Supply Norm	0.00130	-0.00090	-0.00154
	-0.00231	-0.00143	-0.00149
Pre Auction Volume	0.00792	-0.0278**	
	-0.01720	-0.01340	
Constant	0.983***	1.033***	1.043***
	-0.06040	-0.03490	-0.03610
Observations	379	379	379
R-squared	0.03	0.17	0.14

*** p<0.01, ** p<0.05, * p<0.1

Table 12: Variable Definitions

This table describes the dependent and independent vaiables used in various regressions.

Variables	Definition
Independent Variables	
Volatility Norm	Post auction (1 day after) std. dev. Of trraded prices divided by pre-auction std. dev of traded prices
Post Auc Price Norm	Post auction (1 day after) value weighted trraded prices divided by pre-auction value weighted traded prices
VWBid_Norm	Value weighted bid divided by pre auction (one day before) value weighted traded prices
Ex-post Bid Shading	(1-(value weighted bid/pre auction value weighted price)) x 100
Bid Shading	Value weighted bid shading estimated by structural estimation by each bidder in an auction
Dependent Variables	
Goldman Dummy	Takes value 1 for the period after Goldman enter (April 1 2011) and 0 otherwise
BKPD Dummy	Takes value 1 if the primary dealer also have a commercial banking business and 0 otherwise
Not Devolved DvlWk Dummy	Takes value 1 if the successful auction was held in the same week of a devolved auction
Pre Auction Volume	Log of the total volume of trades one day before the auction
Pre Auction Volatility	Std. Dev. of tradeed prices day before the auction
Auction Supply	Log of the notified amount divided by the pre auction (1 day before) volume of trade
Underwriting Commission	Paise per INR 100 of the underwriting cut-off price in the underwriting auction
StandAlone PD Win Norm	Amount won by stand-alone primary dealers in auction normalized by pre-auction volume of trrades
Bank PD Win Norm	Amount won by bank primary dealers in auction normalized by pre-auction volume of trrades
Bank PD Bid Shading	The amount of bid shading from the strucctuural estimation by bank primary dealers
Stand Alone PD Bid Shading	The amount of bid shading from the strucctuural estimation by stand aloneprimary dealers