Auction Mechanisms and Treasury Revenue: Evidence from the Chinese Experiment *

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Abstract

This paper investigates a large-size auction experiment conducted by two Chinese Government Treasury security issuers—the Chinese Development Bank and the Export-Import Bank—to investigate whether Treasury securities should be sold through uniform or discriminatory auction mechanisms. Based on the outcomes of more than three hundred Treasury auctions sold through an alternating auction-rule experiment, we find that auction outcome yield rates of the two auction formats are not statistically different, suggesting revenue equivalence. This equivalence is robust across different revenue measurements.

JEL Classification: C57, C58, D44.

Keywords: Treasury Security Auctions; Discriminatory vs. Uniform-Price Auctions; Revenue Equivalence.

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1 Introduction

Researchers around the world have long been interested in understanding which multi-unit auction format generates a lower yield rate and a higher price for bond issuers. The debate is also of public interest, as a smart Treasury auction market design could potentially generate larger revenues and reduce tax burdens. A seminal paper in the theoretical multi-unit auction literature, Ausubel et al., (2014), finds that the general revenue ranking of uniform and discriminatory auctions is ambiguous, especially when bidders are asymmetric in their type distributions and have asymmetric information.[1] They emphasize that determining the revenue-enhancing pricing rule is, thus, an empirical question, encouraging empirical researchers to further pursue (either counterfactual or direct) comparison of the auction rule outcomes.

In this paper, we exploit an alternating auction-rule experiment conducted between 2012 and 2015 by two large Chinese government banks–the Chinese Development Bank (CDB) and the Export-Import Bank (EIB)–to investigate the revenue ranking of uniform and discriminatory auctions.[2] The total value of the experiment is ¥ 288.7 billion (approximately $43.5 billion). Because the Treasury auction formats are pre-determined by the experiment, the CDB and EIB design an auction format based neither on the bond characteristics, nor on future financial and economic market conditions. Our summary statistics confirm that the auction format used by the CDB and EIB to sell government bonds was not correlated to bond features or market conditions. Consequently, the two auction rules were used in an otherwise similar environment, which allows us to obtain unbiased estimates to assess the effect of a chosen auction rule on yield rate and revenue of Treasury securities.

Using Treasury auction data gathered from the CDB and the EIB alternating auction-rule experiment, we find that, at least in the Chinese government security auctions, the uniform and discriminatory auction formats exhibit revenue equivalence. As far as we know, this study is the first to address this important empirical revenue-comparison question by directly

[1] Notably, the study of Ausubel et al. (2014) derives revenue rankings under either symmetric bidders or symmetric information settings. They also report that, by changing some model setups such as symmetry and risk-neutral assumptions, researchers can derive different revenue rankings.

[2] These banks are government policy banks that finance economic policies and, for this reason, we call the securities issued by the CDB and EIB 'Chinese government bonds.' These two institutions have the same short and long credit ratings awarded by Moody's, Standard & Poor's, and Fitch. Their credit ratings also coincide with the ones awarded by those rating agencies to the other Chinese government bonds issued by the Ministry of Finance (MOF).

comparing the Treasury auction outcomes of two auction rules using real market data from a large-scale alternating auction rule experiment.

Following a series of studies on one-shot auction-rule changes (i.e., single time-point auction rule switching during an investigation period) introduced by the U.S. Treasury in 1973-76 and 1992-93 (see Simon, 1994; Mester, 1995; Nyborg and Sundaresan, 1996; and Malvey and Archibald, 1998), we conduct our empirical analysis using two different approaches.[3] First, we directly compare outcome yields in the primary market between these two auction formats. This direct empirical comparison is important because there is no clear theoretical evidence of revenue superiority (or equivalence) between discriminatory and uniform auctions.[4] Second, we consider the primary market yield normalized by the prior day's government-announced corresponding yield (based on maturity by institution) and compare them across the two auction formats. In both approaches, we find that auction yield rates are not statistically different between uniform and discriminatory auction formats, empirically suggesting revenue equivalence. These results are robust across different subsamples and along the entire quantiles of weighted-average bond primary yield rates, examined by quantile regressions.

Our research is also related to the recent empirical literature on Treasury auctions. Pioneered by the study of Hortaçsu (2002), recent studies build and estimate structural Treasury auction models and base the evaluation of different auction rules on counterfactual simulation (for instance, Hortaçsu and McAdams, 2010, and Kastl, 2011). Nevertheless, the counterfactual results based on structural estimation do not provide clear-cut conclusions about which treasury auction rule generates a lower yield rate and larger revenue. Some studies present results in favor of uniform auctions, while others support discriminatory auctions. Another set of studies reports that the two mechanisms would generate quantitatively similar revenues.[5]

[3]Specifically for 1973-76, the U.S. Treasury conducted 6 uniform and 10 discriminatory auctions, with the auction rule switched from the uniform to the discriminatory format in May 1974 (see Simon, 1994). Moreover, in 1992-93, the U.S. Treasury held 15 uniform (of 2yr and 5yr maturities) and 91 discriminatory (of 3m, 6m, 1yr, 2yr, 3yr, 5yr, and 10yr maturities) auctions (see Nyborg and Sundaresan, 1996). The 2yr and 5yr maturity bond auctions were switched from discriminatory to uniform in September 1992 (see Mester, 1995). Tenorio, 1993 and Kang and Puller, 2008 also investigate one-shot changes from one auction format to another with Zambian foreign exchange and Korean Treasury auctions, respectively.

[4]For example, Bukhchandani and Huang (1989), who proposed a multi-unit common value model of treasury auctions with resale opportunities, show that higher revenue occurs in uniform auctions compared to the discriminatory format. Back and Zender (1993) initiate the discussion that the one-shot switch from the discriminatory to the uniform auction format, which was introduced by the U.S. Treasury in the early 1990s, may decrease the Treasury's revenue. Moreover, under a risk-neutral and symmetric information environment, Wang and Zender (2002) show a revenue advantage in discriminatory auctions compared to uniform auctions. However, in this study, this revenue advantage result may flip when bidders are risk-averse.

[5]The empirical literature has a mixed view on the revenue comparison. Tenorio (1993), Umlauf (1993)

In addition, despite the fact that revenue equivalence is often reported in empirical studies, the ambiguous revenue ranking in the theoretical literature (e.g. Wang and Zender, 2002, and Ausubel et al., 2014) does not necessarily imply revenue equivalence, which warrants careful experimental investigation. The alternating auction rule experiment conducted by the CDB and EIB, which is the focus of this paper, enables us to directly compare the primary rates and revenues of Treasury securities sold through uniform and discriminatory auctions, complementing previous structural estimations and counterfactual results. As bidders in these auctions were exposed to the alternating rules with an equivalent market environment, our empirical finding sheds light on the long-standing debate on Treasury auction mechanism design.

The paper is organized in the following manner. In Section 2, we explain the market background and, in Section 3, we explain the experiment and the data. Section 4 presents the empirical analysis, and we discuss our results in Section 5. The conclusion is presented in Section 6.

2 Market background

In this section, we first introduce the two government policy-bank bond issuers–the CDB and the EIB–which conducted the alternating rule experiment in the People's Republic of China (henceforth, PRC). We then present the credit ratings of these two institutions, showing that they have identical ratings. Next, we explain the yield curve of each institution's securities, which is publicly announced each business day. Finally, we describe the auction rule announcement timings.

2.1 Two government security issuers (CDB and EIB)

The two bond issuers investigated here are the CDB and the EIB. The CDB issues bonds to finance national development projects initiated by the government for both domestic and

and Armantier and Sbai (2006) report the revenue advantage of the uniform-price format, while Simon (1994) and Fevrier et al. (2004) support the discriminatory format. However, the most popular finding in empirical studies, such as Nyborg and Sundaresan (1996), Malvey et al. (1998), Hortaçsu (2002), Hortaçsu and McAdams (2010) and Bonaldi, Hortaçsu, and Song (2015), is empirical revenue equivalence with statistically insignificant differences between the two formats in revenue comparisons. Also, see the unique study of Brenner et al. (2009), which investigates revealed preferences of auction mechanism choices among approximately 50 countries.

foreign projects, while the EIB auctions off bonds to raise funds for projects related to exports and high-tech industries. A detailed explanation of the historical background of these two institutions is provided in Barbosa et al. (2018).

2.2 Credit ratings

The CDB and EIB short- and long-term ratings are listed in Table 1. The credit ratings are awarded by three foreign agencies: Moody's, Standard & Poor's, and Fitch. In this table, we also list the ratings of government securities issued by the Ministry of Finance (MOF) as a benchmark reference. We find that all institutions have homogeneous credit ratings within each year, indicating that, from the viewpoint of the rating agencies, all of these government securities are categorized equivalently.

The PRC has distinctive characteristics regarding its fiscal operations. Specifically, the People's Bank of China (the central bank), which governs the CDB and EIB, operates directly under the government. Additionally, the MOF operates directly under the central government. Thus, bonds issued by these institutions are backed by the PRC (see Chen, 2014, for details), and bond market participants perceive that the bonds issued by these institutions are fully backed by the Chinese government (for instance, Chen, 2010; and Li, 2014).[6] As a consequence, the CDB and EIB historically have the same credit ratings, enabling us to compare auction outcomes across institutions.

Finally, although credit ratings were awarded to these bond-issuing institutions (i.e., institutional ratings), there is no credit rating for each government security. As far as we know, these institutions had not solicited any credit analyses from rating agencies prior to 2017.

2.3 Yield curves

We use the market yield curve to normalize the primary market rates, and as a proxy for market volatilities. The secondary market yield data are obtained from the China Central

[6]See Jian Chen (2014), China Finance Publishing House, "Research on the Financial Bonds issued by Policy Banks in the Process of Reform and Transition (Gai ge zhuan xin zhong de zheng ce xing yin hang jing rong zai quan yan jiu)" for political-economy background on the CDB and EIB, indicating that they have Chinese government-guaranteed sovereign credit ratings. Also see Ying Chen (2010), Finance Teaching and Research, "Suggestions to Current Credit Rating of Chinese Bonds (Dang qian wo guo xing yong ping ji de wen ti ji dui ce jian yi)" and Haitao Li (2014), South Journal, "Research on Development of Credit Rating System in Chinese Bond Market (Wo guo zai quan shi chang xing yong ping ji zhi du fa zhan yan jiu)" for details on credit rating equivalence.

Depository & Clearing Co., Ltd. (CCDC). The CCDC is a State Council-approved agency (also authorized by the China Banking Regulatory Commission) that records all government bond-related transactions.

Each business day, the CCDC publicly announces the yield curves for bonds issued by the CDB and EIB, which are based on the previous resale market transactions. These yield curves provide official benchmarks to general investors. Moreover, resale market yield rates, especially for short-term bonds, experience significant volatility. Hence, in our regression analyses, we use a volatility measurement, which is calculated by the variance of the yield curve in the period from 5 days before the previous day of the auction. Each variance is separately derived for each institution and at each corresponding maturity of the auctioned security.

3 The experiment

For the periods of May 2012-July 2014 and July 2013-May 2015, the CDB and EIB alternated the auction rules between the discriminatory and uniform pricing auction formats. The CDB held their weekly (or bi-weekly) auctions on Tuesdays, while the EIB typically held their bi-weekly (or often more sparse) auctions on Fridays. On an auction date, these institutions usually held multiple auctions with bonds of varying maturities.[7] During these market-based experiment periods, the institutions controlled the auction formats and the experiment was not publicly announced. Most importantly, the auction rule choices made by CDB and EIB cannot conceivably be correlated with the observed and unobserved bond characteristics or with financial market variables in our regression models. As we will show, in Section 5, observable bond characteristics and financial and economic market conditions are not correlated with the auction format chosen to sell bonds.

3.1 CDB experiment

During the experimentation period, the CDB conducted a total of 269 auctions. Out of these, 139 were uniform and 130 were discriminatory (see Table 2). Within each (bi-)week, the CDB auctioned off bonds of different maturities (2yr, 3yr, 5yr, and 7yr) with varying

[7]For instance, on April 8th, 2014 (Tuesday, a bid submission date), the CDB auctioned off four types of securities—with 1yr, 3yr, 5yr, and 7yr maturities—through separate auctions.

auction rules.[8] A stylized pattern of this experimentation is shown in Table 3. As the table shows, the auction mechanism alternated between discriminatory and uniform auction rules (for example, see discriminatory auctions on 22 January 2013 and uniform auctions on 29 January 2013). Additionally, for some weeks, the CDB set the discriminatory format for 3yr and 7yr maturity notes, and the uniform format for 5yr notes. However, in the following (bi-) week, all maturities were sold through the uniform auction format.

3.2 EIB experiment

Similarly, the EIB also experimented with their security auction rules. From July 2013 to May 2015, the EIB held 79 auctions: 49 using the uniform format and 30 using the discriminatory format (see Table 2). Although the alternating auction-rule pattern is not as distinctive as that used by the CDB due to fewer and relatively infrequent auctions, the pattern of the EIB's auction rule experiment is as follows. The EIB conducted bi-weekly (or often much longer interval) auctions, held typically on Fridays, usually with two to four different maturities. The EIB alternated the two different auction rules (see Table 3 Panel A – Alternating auction rule by date) for different maturities and, in the latter half of the experimental period, the institution used the two auction rules on the same type of bond when reissuing (see Table 3 Panel B – Alternating auction rule by bond type).[9]

3.3 The timing of auction-rule announcements

During the experimental period of 2012-15, the CDB and EIB were required to strictly follow bond issuance guidelines set by the People's Bank of China.[10] Accordingly, the CDB and EIB made auction-rule announcements three business days in advance. This means that the participants knew which format was going to be used for a given auction only three business

[8]Note that, in addition to the 2yr, 3yr, 5yr and 7yr notes, 1yr bills and 10yr notes were also auctioned off by the CDB. These were always sold through the uniform-pricing format. For this reason, 1yr or 10yr securities are excluded from our regression analyses.

[9]Note that, when reissued, each bond received a new ID; but we also know the old bond id and that allows us to identify the reissue of an old bond.

[10]Source: Official Notice of People's Bank of China (2009), "Administrative Procedures for the Issuance of Financial Bonds in the National Inter-Bank Bond Market (Quan guo yin hang jian shi chang jin rong zhai quan fa xing guan li chao zuo gui cheng)." In these guidelines, a regulation explicitly states that the public notice of a new issuance auction (which includes the auction rule and other information, such as maturity, volume, issue date, etc.) has to be made at least three business days in advance. To the best of our knowledge, there was no annual, quarterly, or monthly issuance/auction schedule announcement made by the CDB and EIB during their experimental periods.

days before the auction date. To illustrate what is known by auction participants at the auction, consider the following example. Suppose auctions are held every Tuesday, and we consider two auctions in two consecutive weeks. Once the first auctionâ€2122s transactions are settled, the outcome of the auction will be made public on Wednesday. Then, institutions will announce the specific details of the second auction (date of the auction, volume, mechanism, corresponding maturity, etc.) on Thursday.[11,12] Hence, ex-ante, bidders do not know the specific value and volume of upcoming auctions nor associated future auction formats of the CDB and EIB. Additionally, based on the time of the announcement, bidders cannot condition their current bids on future auction rules.[13]

4 Auction market data

We obtain data on auction activities in the Chinese bond market from two data sources, the Wind Database and Chinabond.com. The Wind Database is maintained by the Wind Information Co. Ltd., a financial data and information provider in China. Chinabond.com is the official website of the China Central Depository & Clearing Co. Ltd., which is the only government bond depository authorized by the MOF and is responsible for the establishment and operation of the government bond depository system.

The Wind Database provides access to the details of the CDB and EIB bond auctions. Our data contains not only the information of auctioned bonds, such as maturity, auction method, size of auction, and tender subjects (e.g., price or yield), but also the auction outcomes of weighted-average winning yield rate (or price), total demand, number of bidders, number of bids, number of winners, number of winning bids, final coupon rate for each auction, the presence or absence of floating coupons, as well as the highest and the lowest winning bid in discriminatory auctions. We collect supplementary information from Chinabond.com, such as bond types, subsidies, coupon payment, and the frequency of each bond issued by the CDB and EIB.

Our data are at the auction-level. Bid-level data with the identity of bidders are not

[11] A small number of deviations from these stylized announcement patterns were made when there was a long interval between two consecutive auction dates or public holidays.

[12] Specifically, the CDB made a public announcement of the auction rule on a Thursday and bids were submitted on the Tuesday of the following week. The EIB made a public announcement, typically on a Tuesday, and bids were submitted on the Friday of the same week.

[13] We collected data on the public notice date of each issuance/auction. Our data confirm that the CDB and EIB followed the guidelines set by the People's Bank of China.

available due to the restrictive nature of Chinese bond market data. In spite of that limitation, the data generated from the Chinese experiment contain information on Treasury security yield rates in the two experimentally assigned auction formats by an alternating rule.

4.1 Auction rules and market conditions

A potential concern about our empirical strategy would be the possible correlation between the auction format, the bond features, and market conditions. If a specific auction rule is endogenously chosen when the financial market experiences a specific circumstance, then our estimates would be biased, even though we are using experimental data. There are three important reasons why the auction formats are not correlated to unobserved bond and market characteristics. First, under the (bi-) weekly alternating nature of the auction rule choice, as well as the strictly regulated timing of the auction announcement, neither of the unobserved bond characteristics, nor present and future financial and economic market conditions, plausibly have room to influence the auction rule. Second, systematic changes in financial market conditions do not normally occur on a (bi-) weekly basis. Lastly, during the randomizing period of the EIB (described above) two auction rules are used within the same week.

We find statistical evidence that specific auction rules are not associated with a specific bond type, nor are they chosen to match specific financial conditions. Table 5 reports the observables associated with the uniform and discriminatory auctions. In this table, we show the prior day's yield curve, maturity of auctioned security, market volatility, and value of maturing bonds by the institution for a given month. We have provided 95% confidence intervals and the calculated t-values. The results show that these variables are not statistically different between uniform and discriminatory auctions, indicating that bond characteristics and financial market conditions were well balanced during the experiment. For example, the average of the government-announced yield one day before the auction date is 3.685% for uniform auctions, while it is 3.683% for discriminatory auctions. The 95% confidence intervals clearly overlap between uniform and discriminatory auctions, and the calculated t-value is 0.044. Similar conclusions are derived for other variables presented in Table 5.

Considering other regression variables, the timing between two auctions by the institutions is about 8.5 days, and the demand and supply ratio is 2.5. Finally, the floating bonds represent

about 13.5% (or 47) of all auctions. Note that these floating bonds were used only in uniform auctions. Our baseline estimates use all auctions, including the floating ones. In addition, in Section 5.2, we report results without these 47 floating bond auctions and show that these results are qualitatively the same as the ones using the full sample.

4.2 Auction rules and number of bidders

Another concern is the equality of the number of bidders in these two auction formats during the experiment. It is worth noting that, to bid in the primary market, bidders have to be prequalified. Primary market bidders have to go through a rigorous prequalification process and past performance influences the continuation as a primary dealer in the following year. On average, during the experimental period, the CDB had about 76 pre-qualified bidders while the EIB had about 66. Additionally, we observe that more than 90 percent of dealers continue from year to year during the experiment period at each institution. Considering new entrants, the CDB and EIB had about 6 and 5 new entrants, respectively, every year during this period. More importantly, on average, about 88% of primary dealers participate in auctions of both institutions. We observe a similar pattern for the pre- and post-experimental period. More detailed information can be found in Barbosa et al. (2018).

As mentioned before, the institutions experimented with the auction formats, and not with other market conditions. Hence, to examine the equality of number of bidders in the uniform and discriminatory auctions, we need to control for observed market conditions and institutions. In this case, we estimate the number of bidders in an auction, controlling for auction type, institutions, market conditions, time gap between auctions by institutions, demand and supply ratio of bonds, institution effects, year effects, and month effects. Given that the number of bidders is a count, we estimate it using the Poisson Pseudo Maximum Likelihood (PPML) method.[14] We also estimate this regression using the OLS. Table 6 reports these results with and without floating bonds. Our main interest is in the coefficient of the auction mechanism dummy, which takes the value of one when the auction format is discriminatory, and it shows that there is no statistical difference in the number of bidders based on auction rule during the experimental period.

[14]For PPML estimation, the data does not have to follow a Poisson distribution to produce consistent estimates. The only condition required for consistency is the correct specification of the conditional mean of the independent variable (see Santos Silva and Tenreyro, 2006, 2010; Wooldridge, 1999).

Hence, conditional on controls, this experimental environment enables us to conceivably interpret the auction rule variable as conditional mean independent, treating it as exogenously assigned. Taken all together, the treasury auction experimental environment in China is quite advantageous to directly comparing the revenues generated from uniform and discriminatory auctions. In the next section, we provide a primary market analysis.

5 Estimation Results

5.1 Main Results

We begin our analysis by estimating a simple OLS regression. Our dependent variable is the primary market auction-specific weighted-average winning bid rate on a given date, or the winning rate normalized by the prior date's government-announced yield rate (relative winning rate), calculated by institution and maturity. In our base model, we control for floating bonds, monthly effects, and year effects, without any other controls.

The results in Column 1 of Table 7 indicate that the coefficient of primary winning bid rates for uniform and discriminatory auctions are not statistically different. In Column 2, we include the government-announced yield curve as a control for financial market conditions. Additionally, in Column 2 and in all subsequent models, as we have pooled the observations of CDB and EIB auctions, we also include bond-issuer fixed effects to account for any difference between bonds of different issuers that goes beyond their credit risk.[15] Again, our results indicate that there is no statistical difference between uniform and discriminatory auctions' primary winning bid rates. In Column 3, we include all auction and market controls while, in Column 4, we include the number of bidders in addition to other controls. As in other columns, our results indicate that there is no statistical difference at conventional levels between uniform and discriminatory auctions' primary winning bid rates. Note also that, from our estimations in Table 7, the coefficients on the discriminatory auction dummy are close to zero. They vary from -0.038% (or -3.8 bps) to 0.044% (4.4 bps), which corresponds to 1.03% and 1.19% of the mean primary rate of the bonds in our sample (the mean primary rate is 3.685%, i.e., 368.5 bps).

In Columns 5-7 of Table 7, we present results for the relative primary rate. Like our results

[15]In Section 2, we show that CDB and EIB have identical credit ratings, which means that their securities have a credit risk.

in Columns 1-4, these results also indicate that there is no difference between the primary rates of bonds issued through uniform and discriminatory auction formats.

5.2 Robustness Tests

5.2.1 High and Low primary rates in Discriminatory Auctions

In the previous estimation, we only consider the auction-specific weighted average winning bids. Even though this is not an issue in uniform auctions, one could argue that the difference between auction formats might differ based on the high and low primary rates observed in discriminatory auctions. To address this concern, we re-estimate our models with the highest and lowest winning primary bids for discriminatory auctions. Note that, in discriminatory auctions, the average range between high and low winning bids is 0.032% with a standard deviation of 0.026.

In Table 8, we report the results for weighted-average primary winning rate-based uniform auctions and highest winning bids of discriminatory auctions. In Table 9, we repeat the exercise with the lowest winning bids for discriminatory auctions. Our results indicate that the findings are robust. It shows that our main finding-that there is no statistical difference between uniform and discriminatory formats–holds for the highest and lowest bids of discriminatory auctions compared to uniform auctions as well.

5.2.2 Effect on the Distribution of Bids

Another concern might be that our results may not hold for the full distribution. To address this issue, we re-estimate the empirical models using the quantile regression method for the 15^{th}, 25^{th}, 50^{th}, 75^{th} and 85^{th} quantiles. We present these estimated results in Tables 10-12. Note that these empirical specifications are similar to the ones presented in Table 7, Columns 4 and 7. The results are qualitatively similar to the ones shown in the OLS tables and indicate that there is no significant difference between uniform and discriminatory auctions in general. Note that, in Table A.4, when comparing the lowest winning bids of discriminatory auctions with uniform winning bid rates, we observe that the discriminatory auction rate is lower by -0.047% (-4.7 bps) compared to uniform auctions in the 75^{th} quantile.

5.2.3 Restricted Sample: Without Floating Bonds

As mentioned before, we observed 47 floating bonds, auctioned off using the uniform auction format. As a robustness check, we drop these 47 auctions and re-estimate our main empirical models. We report OLS results in Table 13. The first four columns report results for primary rates for uniform and discriminatory auctions. In Columns 5-8, we report results using the highest winning rates while, in Columns 9-12, we use the lowest winning rates of discriminatory auctions. In all odd-numbered columns, we do not include any market or auction controls other than year and month effects. We include all controls in the empirical models in the even-numbered columns. As in our early estimations with the full sample, the results indicate that there is no statistical difference between uniform auction primary rates and discriminatory auction primary rates. We also estimate these specifications using quantile regression methods, obtaining qualitatively similar results, which indicate that there is no statistical difference between primary rates generated using either uniform or discriminatory auction formats. We do not present these results but can provide them upon request.

5.2.4 CDB vs. EIB

Note that this experiment was conducted by two institutions independently. Hence, we next want to examine whether there are any differences in the primary market rates between uniform and discriminatory auctions by institution. To do this, we re-estimate the models presented in Table 7, Columns 4 and 7, by institution. We present these results in Table 14. In Columns 1 and 2, we present the results for the CDB with and without floating bonds. In Column 3, we report the results for the EIB. In these columns, the dependent variable is the primary market rate. In Columns 4-6, we present the results for the relative primary market rates. All columns indicate that, regardless of the institution, the revenues generated from uniform or discriminatory auctions have no statistical difference.

6 Conclusion

We investigate a large-size auction experiment conducted by two Chinese Government Treasury security issuers—the CDB and the EIB—to investigate whether treasury securities should be sold through uniform or discriminatory auction mechanisms. Based on the outcomes of

348 Treasury auctions with alternating auction rule experimentations, we find that auction outcome yield rates are not statistically different between the two auction formats, suggesting revenue equivalence.

Our observed empirical revenue equivalence results are connected to preceding influential works as recent developments in the structural Treasury auction literature provide insightful views on market design. For instance, Kang and Puller (2008) conclude that, in Korean Treasury auctions, there is a slight revenue advantage for the discriminatory format although the revenue difference between the two formats is quite small due to the competitiveness of the Korean Treasury auction market. The number of bidders in Korean auctions is much smaller than (indeed, less than half of) Chinese auctions; thus, the Chinese market is more competitive than the Korean in terms of the number of bidders. Consequently, our empirical finding in China is in line with the competitiveness finding in Korea. Next, Hortaçsu and McAdams (2010) report that, in their counterfactual simulation of Turkish Treasury auctions, switching from the discriminatory to the uniform format does not significantly increase revenue. Their simulation result is quite similar to our finding. In fact, their empirical finding is quite robust as they estimate and counterfactually use upper and lower bounds of a marginal value distribution. Lastly, and most recently, Bonaldi, Hortaçsu, and Song (2015) report that, in the Federal Reserve's Mortgage-Backed Security auctions, there is a "negligible" revenue difference between the discriminatory format and truthful bidding uniform price auction (which works as a benchmark in their study), with mixed directions of revenue change when they counterfactually simulate each auction. Our direct comparison with alternating auction rules complements these prominent counterfactual studies, by adding market-based experimental support for empirical revenue equivalence between uniform and discriminatory auctions.

Although the Chinese experiment enables us to directly compare auction outcomes and provide inference on which Treasury auction rule generates lower yield rate (larger revenues), our study has some limitations. The lack of bid-level data with information about the identity of bidders does not allow us to study the bidding behavior of auction participants. Thus, we leave for a future study an investigation of asymmetric and bidder-specific heterogeneous behavior in Treasury auctions.

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Table 1: Chinese government and policy banks' security credit ratings

Year	Fitch			Moody's			Standard & Poor's		
	MOF	CDB	EIB	MOF	CDB	EIB	MOF	CDB	EIB
Panel A: Long-term									
2012	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
2013	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
2014	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
2015	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
Panel B: Short-term									
2012	F1	F1	F1	P-1	—	—	A-1+	A-1+	A-1+
2013	F1	F1	F1	P-1	—	—	A-1+	A-1+	A-1+
2014	F1	F1	F1	P-1	P-1	—	A-1+	A-1+	A-1+
2015	F1	F1	F1	P-1	P-1	—	A-1+	A-1+	A-1+

This table reports the long-term and short-term credit ratings awarded by Moody's, Standard Poor's, and Fitch to the Chinese government bonds issued by the Minister of Finance (MOF), the Chinese Development Bank (CDB) and the Export- Import Bank (EIB). If a rate was updated in the middle of a calendar year, the updated rate is listed "—" denotes that no rate was given by a credit rating agency.

Table 2: T–bill distribution by auction type and institution during the auction-rule experiment

Financial institution	Auction format		Total
	Discriminatory	Uniform	
CDB	130	139	269
EIB	30	49	79
Total	160	188	348

This table reports number of bonds that were sold by the CDB and the EIB using uniform and discriminatory auction during the alternating auction-rule experiment.

Table 3: Example of the alternating auction-rule experiment's pattern for the CDB

Date	Maturity in years	Auction mechanism
Jan 08, 2013	3, 5, 7	Discriminatory
Jan 15, 2013	3, 5, 7	Uniform
Jan 22, 2013	5, 7	Discriminatory
Jan 29, 2013	3, 5, 7	Uniform
Feb 05, 2013	3, 5, 7	Discriminatory
Feb 19, 2013	3, 5, 7	Uniform
Apr 09, 2013	3, 7	Discriminatory
Apr 16, 2013	3, 7	Uniform
Apr 23, 2013	3, 7	Discriminatory
May 07, 2013	3, 7	Uniform
May 14, 2013	3, 7	Discriminatory
May 21, 2013	3, 7	Uniform
Jul 16, 2013	3, 5, 7	Discriminatory
Jul 23, 2013	3, 5, 7	Uniform
Jul 30, 2013	3, 5, 7	Discriminatory

This table reports the stylized pattern of this alternating auction-rule experiment conducted by the CDB. The table shows that the auction mechanism alternated between discriminatory and uniform auction rules. Note that all bills (maturity less or equal to one year) and bonds (maturity equal or more than 10 years) were sold using uniform. The alternating auction-rule experiment period for CDB was from May 2012 – July 2014.

Table 4: Example of the alternating auction-rule experiment's patterns for the EIB

Date	Bond ID	Maturity in years	Auction mechanism
Panel A: Alternating auction rule by date			
Jul 31, 2013		2 (t)	Discriminatory (Uniform)
Aug 15, 2013		2 (t)	Discriminatory (Uniform)
Sep 24, 2013		2 (t)	Discriminatory (Uniform)
Oct 21, 2013		2 (t)	Uniform (Discriminatory)
Nov 04, 2013		2 (t)	Uniform (Discriminatory)
Apr 11, 2014		3 (t)	Discriminatory (Uniform)
May 15, 2014		3 (t)	Uniform (Discriminatory)
May 23, 2014		3 (t)	Discriminatory (Uniform)
Jun 06, 2014		3 (t)	Uniform (Discriminatory)
Panel B: Alternating auction rule by bond type			
Nov 28, 2014	14 EXIM 78 (initial)	2	Discriminatory
Dec 04, 2014	14 EXIM 78 (reissue)	2	Uniform
Dec 17, 2014	14 EXIM 78 (reissue)	2	Discriminatory
Apr 15, 2015	15 EXIM 09 (initial)	3	Uniform
Apr 24, 2015	15 EXIM 09 (reissue)	3	Uniform
Apr 30, 2015	15 EXIM 09 (reissue)	3	Uniform
May 06, 2015	15 EXIM 09 (reissue)	3	Discriminatory
May 13, 2015	15 EXIM 09 (reissue)	3	Discriminatory
May 21, 2015	15 EXIM 09 (reissue)	3	Discriminatory

This table reports the stylized pattern of this alternating auction-rule experiment conducted by the EIB. The EIB conducted bi-weekly (or often much longer interval) auctions, held typically on Fridays, usually with two to four different maturities. The EIB alternated the two different auction rules for different maturities (Panel A – Alternating auction rule by date) and, in the latter half of the experimental period, the institution used the two auction rules on the same type of bond when reissuing (Panel B – Alternating auction rule by bond type). The alternating auction-rule experiment period for CDB was from July 2013 – May 2015. The index t in the upper panel denotes other maturity in years that were auctioned off in the same day.

Table 5: Results of the balance test for covariates

Variable	Uniform	Discriminatory	t-Value
Government announced yield one day before the auction date	3.685	3.683	0.044
	[3.617, 3.753]	[3.612, 3.753]	
Duration	4.199	4.418	-1.492
	[4.026, 4.371]	[4.178, 4.658]	
Volatility	0.026	0.029	-1.632
	[0.023, 0.028]	[0.026, 0.032]	
Log value of maturing bonds by institution for a	14.505	14.672	-1.013
given month	[14.265, 14.746]	[14.461, 14.883]	

This table reports the mean, the 95% confidence intervals and the calculated t-values for *prior day's yield curve*, *duration*, *market volatility*, and *value of maturing bonds by the institution for a given month* of the CDB and the EIB government bonds sold through uniform and discriminatory auctions. The variable duration refers to Macaulay duration, which is the weighted average term to maturity of the cash flows from a bond.

Table 6: Regression results for number of bidders

Variable	Number of bidders			
	PPML		OLS	
Discriminatory auctions	-0.000	0.002	0.004	0.006
	(0.014)	(0.014)	(0.016)	(0.015)
Floating bond	-0.038		-0.035	
	(0.026)		(0.028)	
Government announced yield one day before the auction date	0.019	0.005	0.014	-0.003
	(0.024)	(0.025)	(0.028)	(0.030)
Log of duration	-0.029	-0.025	-0.030	-0.025
	(0.019)	(0.019)	(0.024)	(0.026)
Log of demand/supply	0.250***	0.224***	0.272***	0.242***
	(0.026)	(0.026)	(0.033)	(0.034)
Volatility	0.055	-0.082	0.088	-0.041
	(0.266)	(0.272)	(0.293)	(0.304)
Log of time lag between auctions by institution	-0.004	0.009	-0.009	0.006
	(0.011)	(0.012)	(0.012)	(0.013)
Log value of maturing bonds by institution for a	-0.001	-0.001	-0.002	-0.002
given month	(0.006)	(0.006)	(0.007)	(0.007)
Month effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
Bank effects	Yes	Yes	Yes	Yes
Observations	348	301	348	301
R^2	0.567	0.594	0.539	0.557

This table estimates the number of bidders in an auction, controlling for auction type, institutions, market conditions, time gap between auctions by institutions, demand and supply ratio of bonds, institution effects, year effects, and month effects. The variable duration refers to Macaulay duration, which is the weighted average term to maturity of the cash flows from a bond. We estimate this using the Poisson Pseudo Maximum Likelihood (PPML) method and also using the OLS. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Regression results for primary rate

Variable	Primary rate				Relative primary rate		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Discriminatory auctions	-0.038	0.038	0.044	0.038	0.008	0.008	0.007
	(0.064)	(0.042)	(0.047)	(0.040)	(0.011)	(0.013)	(0.011)
Floating bond	-0.776***	-0.525***	-0.433***	-0.381***	-0.163***	-0.144***	-0.130***
	(0.154)	(0.126)	(0.123)	(0.122)	(0.037)	(0.036)	(0.035)
Government announced yield one day before the auction date		1.153***	1.287***	1.267***			
		(0.083)	(0.090)	(0.081)			
Log of duration			-0.210***	-0.165**		-0.051***	-0.041**
			(0.074)	(0.065)		(0.019)	(0.017)
Log of demand/supply			0.036	-0.365***		0.008	-0.093***
			(0.105)	(0.107)		(0.029)	(0.028)
Volatility			1.254	1.124		0.413	0.363
			(1.041)	(0.996)		(0.259)	(0.259)
Log of time lag between auctions by institution			-0.048	-0.034		-0.014	-0.011
			(0.042)	(0.039)		(0.012)	(0.011)
Log value of maturing bonds by institution for a			-0.025**	-0.022*		-0.007**	-0.006*
given month			(0.012)	(0.012)		(0.003)	(0.003)
Log number of bidders				1.471***			0.370***
				(0.335)			(0.080)
Month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank effects			Yes	Yes		Yes	Yes
Observations	348	348	348	348	348	348	348
R^2	0.565	0.735	0.748	0.796	0.290	0.325	0.429

This table reports OLS regressions of the auctioned bond yield rate on a variable dummy which takes the value of one when auction format is discriminatory. Our dependent variables are the primary market auction-specific weighted-average winning bid rate on a given date (Columns 1-4), and the winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 5-7). In column (1), our base model, we control for floating bonds, monthly effects, and year effects, without any other controls. In Column 2, we include the government-announced yield curve as a control for financial market conditions. Additionally, in Column 3 and all subsequent models, as we have pooled the observations of CDB and EIB auctions, we also include bond-issuer fixed effects to account for any difference between bonds of different issuers that goes beyond their credit risk. In Column 3, we include all auction and market controls, while in Column 4, we include the number of bidders in addition to other controls. In columns 5-7, we present results for the relative primary rate, and the control in those columns are the same as the ones in columns 2-4. The variable duration refers to Macaulay duration, which is the weighted average term to maturity of the cash flows from a bond. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8: Regression results for primary rate with highest discriminatory auction winning bids

Variable	Primary rate				Relative primary rate		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Discriminatory auctions	-0.013	0.063	0.071	0.066	0.015	0.015	0.014
	(0.064)	(0.042)	(0.046)	(0.040)	(0.011)	(0.012)	(0.011)
Floating bond	-0.773***	-0.521***	-0.429***	-0.377***	-0.163***	-0.143***	-0.129***
	(0.154)	(0.125)	(0.122)	(0.122)	(0.037)	(0.036)	(0.035)
Government announced yield one day before the auction date		1.154***	1.284***	1.264***			
		(0.082)	(0.089)	(0.081)			
Log of duration			-0.206***	-0.162**		-0.051***	-0.041**
			(0.074)	(0.065)		(0.019)	(0.017)
Log of demand/supply			0.023	-0.377***		0.004	-0.096***
			(0.104)	(0.106)		(0.028)	(0.028)
Volatility			1.317	1.187		0.423	0.373
			(1.041)	(0.997)		(0.259)	(0.259)
Log of time lag between auctions by institution			-0.047	-0.033		-0.014	-0.011
			(0.042)	(0.039)		(0.012)	(0.011)
Log value of maturing bonds by institution for a			-0.025**	-0.022*		-0.007**	-0.006*
given month			(0.012)	(0.012)		(0.003)	(0.003)
Log number of bidders				1.471***			0.369***
				(0.336)			(0.080)
Month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank effects			Yes	Yes		Yes	Yes
Observations	348	348	348	348	348	348	348
R^2	0.568	0.737	0.750	0.797	0.296	0.330	0.434

This table reports OLS regressions of the auctioned bond yield rate on a variable dummy which takes the value of one when auction format is discriminatory. For uniform auctions, our dependent variables are the primary market auction-specific winning bid rate on a given date (Columns 1-4), and the winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 5-7). For discriminatory auctions, our dependent variable are the primary market auction-specific highest winning bid rate on a given date (Columns 1-4), and the highest winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 5-7). In column (1), our base model, we control for floating bonds, monthly effects, and year effects, without any other controls. In Column 2, we include the government-announced yield curve as a control for financial market conditions. Additionally, in Column 3 and all subsequent models, as we have pooled the observations of CDB and EIB auctions, we also include bond-issuer fixed effects to account for any difference between bonds of different issuers that goes beyond their credit risk. In Column 3, we include all auction and market controls, while in Column 4, we include the number of bidders in addition to other controls. In columns 5-7, we present results for the relative primary rate, and the control in those columns are the same as the ones in columns 2-4. The variable duration refers to Macaulay duration, which is the weighted average term to maturity of the cash flows from a bond. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Regression results for primary rate with lowest discriminatory auction winning bids

Variable	Primary rate				Relative primary rate		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Discriminatory auctions	-0.047	0.029	0.035	0.029	0.006	0.005	0.004
	(0.064)	(0.042)	(0.047)	(0.040)	(0.011)	(0.013)	(0.011)
Floating bond	-0.778***	-0.526***	-0.435***	-0.382***	-0.164***	-0.144***	-0.130***
	(0.155)	(0.126)	(0.123)	(0.122)	(0.037)	(0.036)	(0.035)
Government announced yield one day before the auction date		1.157***	1.282***	1.261***			
		(0.083)	(0.090)	(0.082)			
Log of duration			-0.205***	-0.160**		-0.050***	-0.041**
			(0.074)	(0.065)		(0.019)	(0.017)
Log of demand/supply			0.034	-0.367***		0.007	-0.093***
			(0.105)	(0.107)		(0.029)	(0.028)
Volatility			1.239	1.108		0.405	0.354
			(1.043)	(0.999)		(0.259)	(0.259)
Log of time lag between auctions by institution			-0.047	-0.034		-0.014	-0.011
			(0.042)	(0.039)		(0.012)	(0.011)
Log value of maturing bonds by institution for a			-0.025**	-0.022*		-0.007**	-0.006*
given month			(0.012)	(0.012)		(0.003)	(0.003)
Log number of bidders				1.476***			0.371***
				(0.335)			(0.080)
Month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank effects			Yes	Yes		Yes	Yes
Observations	348	348	348	348	348	348	348
R^2	0.563	0.734	0.747	0.795	0.287	0.320	0.426

This table reports OLS regressions of the auctioned bond yield rate on a variable dummy which takes the value of one when auction format is discriminatory. For uniform auctions, our dependent variables are the primary market auction-specific winning bid rate on a given date (Columns 1-4), and the winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 5-7). For discriminatory auctions, our dependent variable are the primary market auction-specific lowest winning bid rate on a given date (Columns 1-4), and the lowest winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 5-7). In column (1), our base model, we control for floating bonds, monthly effects, and year effects, without any other controls. In Column 2, we include the government-announced yield curve as a control for financial market conditions. Additionally, in Column 3 and all subsequent models, as we have pooled the observations of CDB and EIB auctions, we also include bond-issuer fixed effects to account for any difference between bonds of different issuers that goes beyond their credit risk. In Column 3, we include all auction and market controls, while in Column 4, we include the number of bidders in addition to other controls. In columns 5-7, we present results for the relative primary rate, and the control in those columns are the same as the ones in columns 2-4. The variable duration refers to Macaulay duration, which is the weighted average term to maturity of the cash flows from a bond. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 10: Quantile regression results for primary rate

Variable	Primary rate					Relative primary rate				
	Quantile					Quantile				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(0.15)	(0.25)	(0.50)	(0.75)	(0.85)	(0.15)	(0.25)	(0.50)	(0.75)	(0.85)
Discriminatory auctions	-0.024	-0.024	-0.015	-0.033	-0.034	-0.011	-0.011	-0.006	-0.012	-0.009
	(0.049)	(0.030)	(0.026)	(0.023)	(0.034)	(0.013)	(0.011)	(0.007)	(0.010)	(0.009)
Government announced yield one day	1.355***	1.418***	1.354***	1.292***	1.261***					
before the auction date	(0.107)	(0.102)	(0.086)	(0.076)	(0.075)					
Month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348	348	348	348	348	348
R^2	0.625	0.629	0.662	0.673	0.675	0.435	0.322	0.209	0.248	0.317

This table reports quantile regressions for the 15^{th}, 25^{th}, 50^{th}, 75^{th} and 85^{th} quantiles of the auctioned bond yield rate on a variable dummy which takes the value of one when auction format is discriminatory. Our dependent variables are the primary market auction-specific weighted-average winning bid rate on a given date (Columns 1-5), and the winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 6-10). All models include controls for floating bonds, duration, demand/supply, volatility, time lag between auctions by institution, value of maturing bonds by institution for a given month, and the number of bidders. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 11: Quantile regression results for primary rate with highest discriminatory auction winning bids

Variable	Primary rate					Relative primary rate				
	Quantile					Quantile				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(0.15)	(0.25)	(0.50)	(0.75)	(0.85)	(0.15)	(0.25)	(0.50)	(0.75)	(0.85)
Discriminatory auctions	-0.005	-0.004	0.008	0.003	-0.008	0.000	-0.005	0.000	-0.002	-0.002
	(0.041)	(0.043)	(0.028)	(0.021)	(0.032)	(0.014)	(0.011)	(0.005)	(0.007)	(0.008)
Government announced yield one day	1.364***	1.416***	1.352***	1.293***	1.273***					
before the auction date	(0.128)	(0.067)	(0.074)	(0.111)	(0.083)					
Month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348	348	348	348	348	348
R^2	0.628	0.630	0.662	0.675	0.677	0.436	0.322	0.206	0.249	0.318

This table reports quantile regressions for the 15^{th}, 25^{th}, 50^{th}, 75^{th} and 85^{th} quantiles of the auctioned bond yield rate on a variable dummy which takes the value of one when auction format is discriminatory. For uniform auctions, our dependent variables are the primary market auction-specific winning bid rate on a given date (Columns 1-5), and the winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 6-10). For discriminatory auctions, our dependent variable are the primary market auction-specific highest winning bid rate on a given date (Columns 1-5), and the highest winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 5-10). All models include controls for floating bonds, duration, demand/supply, volatility, time lag between auctions by institution, value of maturing bonds by institution for a given month, and the number of bidders. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 12: Quantile regression results for primary rate with lowest discriminatory auction winning bids

Variable	Primary rate					Relative primary rate				
	Quantile					Quantile				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	(0.15)	(0.25)	(0.50)	(0.75)	(0.85)	(0.15)	(0.25)	(0.50)	(0.75)	(0.85)
Discriminatory auctions	-0.040	-0.038	-0.020	-0.047**	-0.036	-0.012	-0.015	-0.007	-0.014*	-0.013
	(0.056)	(0.036)	(0.030)	(0.021)	(0.028)	(0.013)	(0.012)	(0.007)	(0.008)	(0.008)
Government announced yield one day	1.358***	1.412***	1.353***	1.297***	1.262***					
before the auction date	(0.087)	(0.082)	(0.091)	(0.098)	(0.095)					
Month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348	348	348	348	348	348
R^2	0.614	0.626	0.661	0.673	0.676	0.433	0.319	0.206	0.247	0.314

This table reports quantile regressions for the 15^{th}, 25^{th}, 50^{th}, 75^{th} and 85^{th} quantiles of the auctioned bond yield rate on a variable dummy which takes the value of one when auction format is discriminatory. For uniform auctions, our dependent variables are the primary market auction-specific winning bid rate on a given date (Columns 1-5), and the winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 6-10). For discriminatory auctions, our dependent variable are the primary market auction-specific lowest winning bid rate on a given date (Columns 1-5), and the lowest winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 5-10). All models include controls for floating bonds, duration, demand/supply, volatility, time lag between auctions by institution, value of maturing bonds by institution for a given month, and the number of bidders. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 13: Regression results for primary rate without floating bonds

Variable	Primary rate		Relative primary rate		Primary rate		Relative primary rate		Primary rate		Relative primary rate	
	Discriminatory auction winning bid rate											
	Average				Highest				Lowest			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Discriminatory auctions	-0.073	0.004	-0.003	-0.003	-0.048	0.032	0.004	0.004	-0.082	-0.005	-0.005	-0.006
	(0.063)	(0.039)	(0.010)	(0.010)	(0.062)	(0.039)	(0.010)	(0.010)	(0.063)	(0.039)	(0.010)	(0.010)
Government announced		1.310***				1.306***				1.304***		
yield one day before		(0.063)				(0.064)				(0.064)		
the auction date												
Log of duration		-0.089*		-0.018		-0.086*		-0.018		-0.084		-0.017
		(0.051)		(0.012)		(0.051)		(0.012)		(0.051)		(0.012)
Log of demand/supply		-0.311***		-0.078**		-0.326***		-0.082***		-0.313***		-0.079**
		(0.117)		(0.030)		(0.116)		(0.030)		(0.117)		(0.030)
Volatility		0.772		0.289		0.832		0.298		0.751		0.279
		(0.858)		(0.206)		(0.861)		(0.206)		(0.861)		(0.206)
Log of time lag between		-0.005		-0.000		-0.004		-0.000		-0.005		-0.000
auctions by institution		(0.027)		(0.007)		(0.027)		(0.007)		(0.027)		(0.007)
Log value of maturing		-0.034***		-0.009***		-0.034***		-0.009***		-0.034***		-0.009***
bonds by institution		(0.012)		(0.003)		(0.012)		(0.003)		(0.012)		(0.003)
for a given month												
Log number of bidders		1.308***		0.301***		1.305***		0.300***		1.311***		0.302***
		(0.413)		(0.095)		(0.414)		(0.096)		(0.413)		(0.096)
Month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank effects		Yes		Yes		Yes		Yes		Yes		Yes
Observations	301	301	301	301	301	301	301	301	301	301	301	301
R^2	0.518	0.857	0.258	0.470	0.516	0.857	0.255	0.467	0.516	0.857	0.257	0.466

This table reports OLS regressions of the auctioned bond yield rate on a variable dummy which takes the value of one when auction format is discriminatory. We removed from the sample all floating bonds. For uniform auctions, our dependent variables are the primary market auction-specific winning bid rate on a given date (Columns 1-2, 5-6, and 9-10), and the winning rate normalized by the prior date's government-announced yield rate, calculated by institution and maturity – relative winning rate (Columns 3-4, 7-8, and 11-12). For discriminatory auctions, our dependent variables are the primary market auction-specific weighted-average winning bid rate on a given date (Columns 1-2), the primary market auction-specific highest winning bid rate on a given date (Columns 5-6), and the primary market auction-specific lowest winning bid rate on a given date (Columns 9-10). In columns 3-4, 7-8, and 11-12, respectively, our dependent variable for discriminatory auctions are the primary market auction-specific weighted-average, highest and lowest normalized by the prior date's government-announced yield rate calculated by institution and maturity. In the odd-number columns, we control for monthly effects, and year effects, without any other controls. In the even-number columns, we include the government-announced yield curve as a control for financial market conditions, and bond-issuer fixed effects. The variable duration refers to Macaulay duration, which is the weighted average term to maturity of the cash flows from a bond. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 14: Regression results for primary rate by institution

Variable	Primary rate			Relative primary rate		
	CDB		EIB	CDB		EIB
	(1)	(2)	(3)	(4)	(5)	(6)
Discriminatory auctions	0.019	-0.029	-0.017	0.004	-0.009	-0.003
	(0.047)	(0.043)	(0.038)	(0.013)	(0.011)	(0.011)
Floating bond	-0.362***			-0.127***		
	(0.132)			(0.037)		
Government announced yield	0.893***	0.986***	1.076***			
one day before the auction date	(0.153)	(0.156)	(0.167)			
Month effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	269	222	79	269	222	79
R^2	0.793	0.850	0.972	0.448	0.512	0.821

This table examines whether there are any differences in the primary market rates between uniform and discriminatory auctions by institution. We estimate the models presented in Table 7, Columns 4 and 7, by institution. In Columns 1 and 2, we present the results for the CDB with and without floating bonds. In Column 3, we report the results for the EIB. In these columns, the dependent variable is the primary market rate. In Columns 4-6, we present the results for the relative primary market rates, which is the primary market auction-specific weighted-average normalized by the prior date's government-announced yield rate calculated by institution and maturity. Models in Columns 1 and 4 include controls for floating bonds. All models include, duration, demand/supply, volatility, time lag between auctions by institution, value of maturing bonds by institution for a given month, and the number of bidders. Robust standard errors are in parentheses, and p-values are denoted by asterisks according to the following scheme: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.