Auction Mechanisms and Treasury Revenue: Evidence from the Chinese Experiment

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Motivation

- 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 general revenue ranking of uniform and discriminatory auctions is ambiguous, especially when bidders are asymmetric in their type distributions and have asymmetric information

  $\Rightarrow$ Back and Zender (1993), Wang and Zender (2002), Ausubel et al., (2014)

- Series of studies on one-shot auction-rule changes – U.S. Treasury in 1973-76 and 1992-93

  $\Rightarrow$ Simon (1994), Mester (1995), Nyborg and Sundaresan (1996), Malvey and Archibald (1998)

- Structural estimation do not provide clear-cut conclusions about revenue generation

  $\Rightarrow$ Hortaçsu (2002), Hortaçsu and McAdams (2010), Kastl (2011)

What we do

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We find that auction outcome yield rates are not statistically different between the two auction formats, suggesting revenue equivalence

Market background

The total market: about $9 trillion in 2017 (government bond market: about $5.8 trillion)

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The Chinese Development Bank (CDB)

⇒ The CDB was founded in 1994, and its main financial missions are middle- and long-term fund operations for national projects, which are initiated by the central government

- Started to issue policy-bank bonds in 1994
- Started using auctions to sell bonds in 1995
  ⇒ Use both uniform and discriminatory auction formats

The Export-Import Bank (EIB)

⇒ The EIB's main missions are to provide financial support to promote the international trade of Chinese mechanical and electronic products

- Was founded in 1994
- Started using auctions to issue bonds in 1999
  ⇒ Use both uniform and discriminatory auction formats

Credit ratings

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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+

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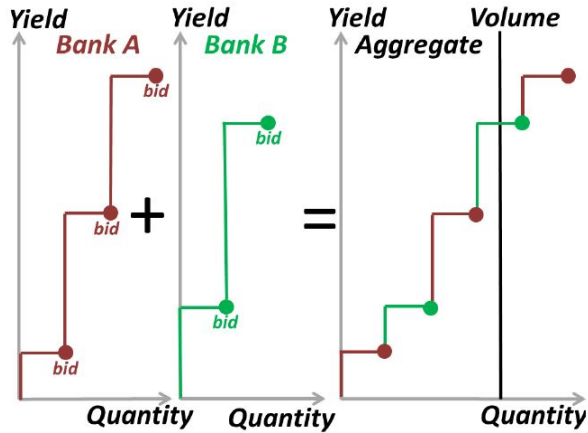
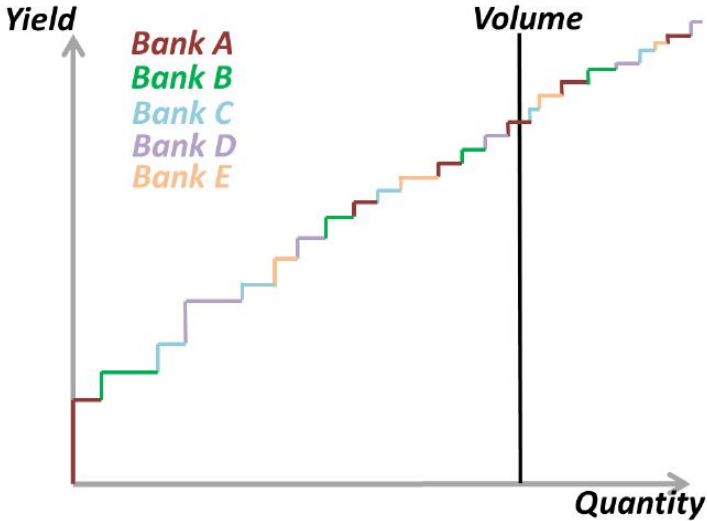
Panel A: Long-term									
2012	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
2013	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
2014	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
2015	A+	A+	A+	Aa3	Aa3	Aa3	AA-	AA-	AA-
Panel B: Short-term									
2012	F1	F1	F1	P-1	—	—	A-1+	A-1+	A-1+
2013	F1	F1	F1	P-1	—	—	A-1+	A-1+	A-1+
2014	F1	F1	F1	P-1	P-1	—	A-1+	A-1+	A-1+
2015	F1	F1	F1	P-1	P-1	—	A-1+	A-1+	A-1+

3. There is no credit rating for each government security

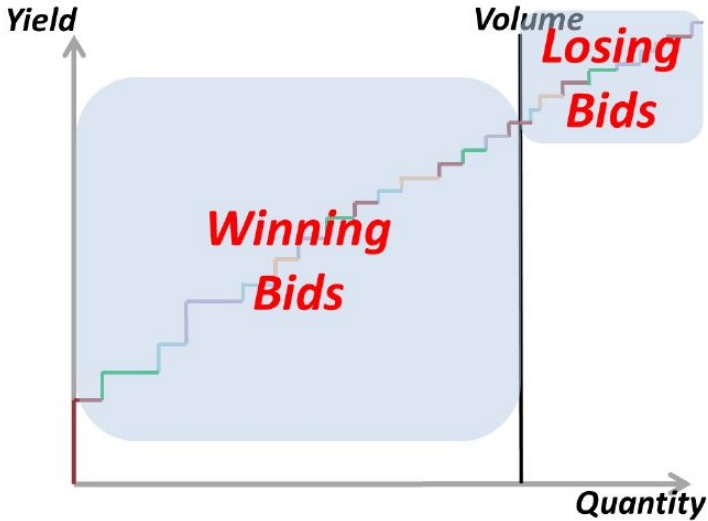
Auction mechanisms



Auction mechanisms



Auction mechanisms



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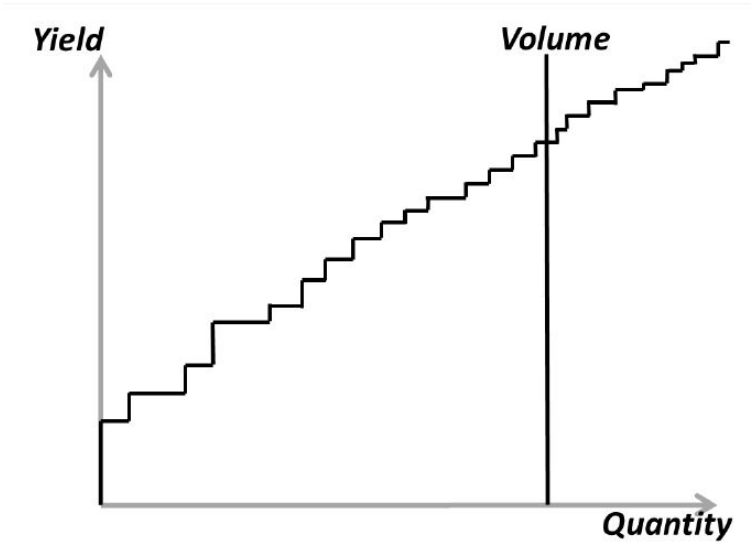
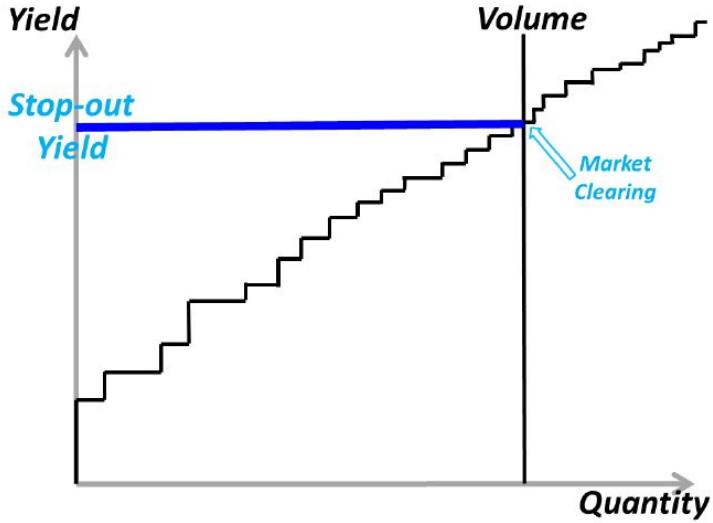
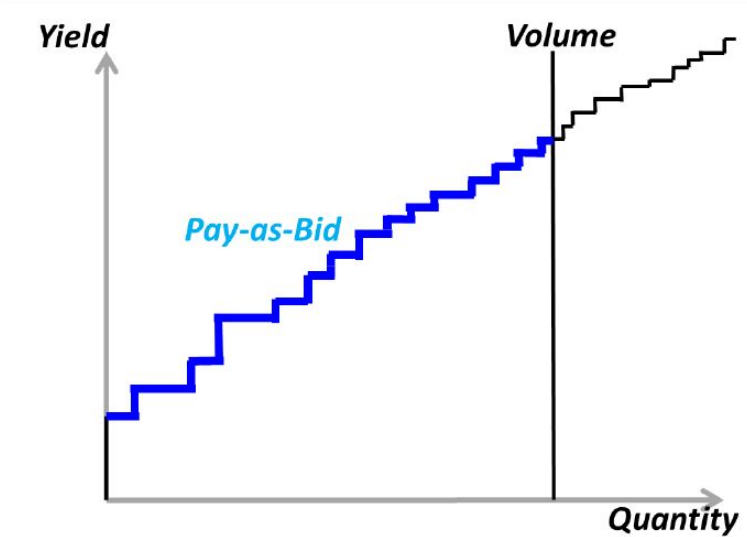


Uniform auction



Discriminatory auction



The experiment

- Alternated the auction rules between the discriminatory and uniform pricing auction formats
- CDB
  1. May 2012-July 2014
  2. Held their weekly (or bi-weekly) auctions on Tuesdays
- EIB
  1. July 2013-May 2015
  2. Held their bi-weekly (or often more sparse) auctions on Fridays

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

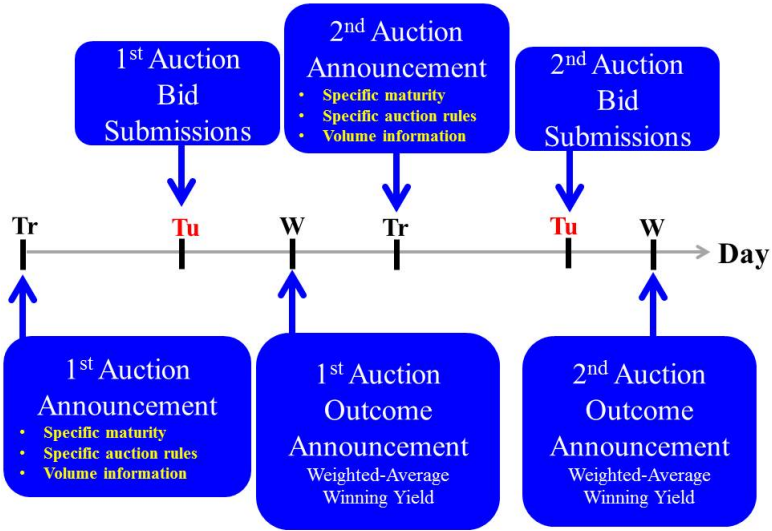
Example of the alternating auction-rule experiment's pattern for the CDB

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

Example of the alternating auction-rule experiment's pattern 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

The timing of auction-rule announcements



Auction market data

Auction level data:

1. Chinabond.com
   ⇒ Official website of the China Central Depository & Clearing Co., Ltd
2. Wind Database
   ⇒ Provides access to details of the primary and secondary market data from 1998 to 2017

Information:

- bond id
- auction method
- maturity
- size of each auction
- tender subjects (e.g. price or rate)
- total demand
- number of bidders and bids
- number of winners and winning bids (high, low, and weighted average)
- final coupon rate for each auction
- presence or absence of floating coupons
- transaction date
- government announced yield curve

Auction rules and market conditions

Possible correlation between the auction format, the bond features, and market conditions

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]	
Log of Duration	1.391	1.417	-0.703
	[1.347, 1.435]	[1.357, 1.477]	
Log of demand/supply	0.886	0.888	-0.093
	[0.830, 0.941]	[0.858, 0.919]	
Volatility	0.026	0.029	-1.604
	[0.023, 0.028]	[0.026, 0.032]	
Log value of maturing bonds by institution for a given month	14.505	14.672	-1.030
	[14.265, 14.746]	[14.461, 14.883]	
First and last week of the month	0.824	0.838	-0.322
	[0.770, 0.879]	[0.780, 0.895]	

Auction rules and number of bidders

- Bidders have to be prequalified
- Credit risk and past performance influences the continuation as a primary dealer
- During the experimental period, the CDB had about 76 pre-qualified bidders while the EIB had about 66
- 90% of dealers continue from year to year at each institution
- The CDB and EIB had about 6 and 5 new entrants, respectively, every year
- More importantly, on average, about 88% of primary dealers participate in auctions of both institutions

Auction rules and number of bidders (cont.)

Variable	Number of bidders			
	PPML		OLS	
Discriminatory auctions	**0.001**	**0.001**	**0.017**	**0.005**
	(0.014)	**(0.014)**	**(0.025)**	**0.016**
Floating bond	-0.053**		-0.051*	
	(0.026)		(0.031)	
Market yield of Chinese bonds	0.015	0.008	0.011	-0.001
one day before the auction date	(0.025)	(0.025)	(0.028)	(0.029)
Log of duration	-0.030	-0.025	-0.032	-0.025
	(0.019)	(0.020)	(0.024)	(0.026)
Log of demand/supply	0.244***	0.227***	0.265***	0.246***
	(0.025)	(0.026)	(0.034)	(0.035)
Volatility	0.065	-0.106	0.339	-0.057
	(0.265)	(0.273)	(0.508)	(0.305)
Log of time lag between auctions	0.016	-0.005	0.016	-0.007
by institution	(0.011)	(0.015)	(0.013)	(0.017)
Log value of maturing bonds by	-0.000	-0.002	-0.001	-0.002
institution for a given month	(0.005)	(0.006)	(0.006)	(0.007)
Institution effects	Yes	Yes	Yes	Yes
First and last week of the month	Yes	Yes	Yes	Yes
Month and year effects	Yes	Yes	Yes	Yes
Market drift	Yes	Yes	Yes	Yes
Observations	348	301	348	301
R^2	0.570	0.593	0.541	0.557

Main results

Variable	Normalized bid					
	OLS			Bayesian		
	(1)	(2)	(3)	(4)	(5)	(6)
Discriminatory auction	0.006	0.008	0.001	-0.006	0.002	0.005
	[-0.085, 0.096]	[-0.089, 0.106]	[-0.081, 0.082]	[-0.070, 0.057]	[-0.067, 0.077]	[-0.071, 0.052]
Floating bond	-0.578***	-0.579***	-0.495***	-0.575	-0.612	-0.482
	[-0.819, -0.336]	[-0.834, -0.323]	[-0.732, -0.259]	[-0.672, -0.479]	[-0.729, -0.510]	[-0.577, -0.395]
Log of duration		-0.115*	-0.073		-0.112	-0.075
		[-0.252, 0.022]	[-0.194, 0.047]		[-0.172, -0.055]	[-0.156, 0.006]
Log of demand/supply		-0.002	-0.389***		-0.006	-0.377
		[-0.213, 0.209]	[-0.594, -0.184]		[-0.106, 0.091]	[-0.452, -0.304]
Volatility		2.269**	2.044**		2.220	2.022
		[0.344, 4.195]	[0.093, 3.995]		[2.128, 2.319]	[1.854, 2.208]
Log of time lag between auctions		0.050	0.025		0.063	0.019
by institution		[-0.072, 0.171]	[-0.087, 0.138]		[0.002, 0.126]	[-0.030, -0.073]
Log value of maturing bonds by		-0.018	-0.016		-0.022	-0.018
institution for a given month		[-0.041, 0.005]	[-0.042, 0.010]		[-0.037, -0.006]	[-0.035, 0.001]
Log number of bidders			1.472***			1.480
			[0.837, 2.106]			[1.406, 1.547]
Institution effects		Yes	Yes		Yes	Yes
First and last week of the month	Yes	Yes	Yes	Yes	Yes	Yes
Month and year effects	Yes	Yes	Yes	Yes	Yes	Yes
Market drift	Yes	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348	348
R^2	0.355	0.376	0.494			
Log marginal likelihood				-246.660	-301.338	-281.949

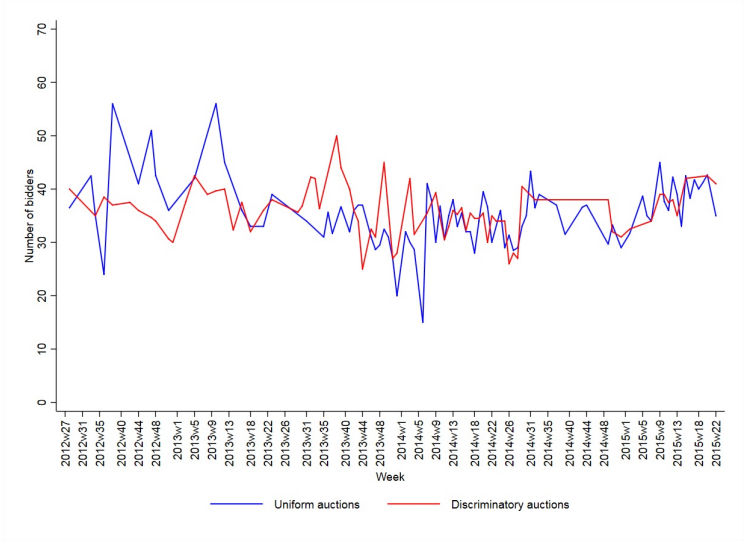
Highest and Lowest primary rates in discriminatory auctions

Variable	Normalized bid			
	OLS		Bayesian	
	Highest	Lowest	Highest	Lowest
	(1)	(2)	(3)	(4)
Discriminatory auction	0.028	-0.007	0.036	-0.012
	[-0.053, 0.110]	[-0.089, 0.074]	[-0.033, 0.101]	[-0.066, 0.042]
Floating bond	-0.491***	-0.497***	-0.488	-0.476
	[-0.727, -0.256]	[-0.733, -0.260]	[-0.565, -0.414]	[-0.571, -0.386]
Auction and market controls	Yes	Yes	Yes	Yes
Institution effects	Yes	Yes	Yes	Yes
First and last week of the month	Yes	Yes	Yes	Yes
Month and year effects	Yes	Yes	Yes	Yes
Market drift	Yes	Yes	Yes	Yes
Observations	348	348	348	348
R^2	0.499	0.492		
Log marginal likelihood			-279.097	-282.579

First-half and second-half of the experiment

Variable	Normalized bid			
	OLS		Bayesian	
	First-half	Second-half	First-half	Second-half
	(1)	(2)	(3)	(4)
Discriminatory auction	-0.021	0.009	-0.063	0.005
	[-0.184, 0.142]	[-0.090, 0.109]	[-0.150, 0.026]	[-0.072, 0.071]
Floating bond	-0.765***	0.160	-0.830	0.183
	[-1.055, -0.475]	[-0.342, 0.662]	[-0.961, -0.703]	[0.100, 0.268]
Auction and market controls	Yes	Yes	Yes	Yes
Institution effects	Yes	Yes	Yes	Yes
First and last week of the month	Yes	Yes	Yes	Yes
Month and year effects	Yes	Yes	Yes	Yes
Market drift	Yes	Yes	Yes	Yes
Observations	148	200	148	200
R^2	0.524	0.547		
Log marginal likelihood			-199.963	-169.182

Weekly average number of bidders by auction formats



Results for number of bidders during the experiment

Variables	Number of bidders	
	PPML	OLS
	(1)	(2)
Discriminatory auctions	-0.074	-2.194
	(0.053)	(1.854)
Second half	-0.008	-0.019
	(0.026)	(0.982)
Second half × Discriminatory auctions	0.011	0.114
	(0.030)	(1.114)
Auction and market controls	Yes	Yes
Institution effects	Yes	Yes
First and last week of the month	Yes	Yes
Month and year effects	Yes	Yes
Market drift	Yes	Yes
Observations	348	348
R^2	0.576	0.590

Restricted sample: without floating bonds

Variable	Normalized bid					
	OLS			Bayesian		
	Average	Highest	Lowest	Average	Highest	Lowest
	(1)	(2)	(3)	(4)	(5)	(6)
Discriminatory auction	-0.006	0.022	-0.015	0.004	0.031	-0.007
	[-0.087, 0.074]	[-0.058, 0.102]	[-0.095, 0.066]	[-0.041, 0.055]	[-0.016, 0.079]	[-0.052, 0.036]
Auction and market controls	Yes	Yes	Yes	Yes	Yes	Yes
Institution effects	Yes	Yes	Yes	Yes	Yes	Yes
First and last week of the month	Yes	Yes	Yes	Yes	Yes	Yes
Month and year effects	Yes	Yes	Yes	Yes	Yes	Yes
Market drift	Yes	Yes	Yes	Yes	Yes	Yes
Observations	301	301	301	301	301	301
R^2	0.482	0.480	0.481			
Log marginal likelihood				-162.404	-162.473	-165.701

Effect on the distribution of bids

Variable	Normalized bid				
	Quantile				
	0.15	0.25	0.50	0.75	0.85
Panel A: with weighted averages of discriminatory auction winning bids					
Discriminatory auction	-0.008	-0.051	-0.037	-0.029	-0.030
	(0.060)	(0.053)	(0.032)	(0.030)	(0.035)
All controls	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348
R^2	0.417	0.327	0.263	0.337	0.406
Panel B: with highest discriminatory auction winning bids					
Discriminatory auction	0.014	-0.016	-0.011	-0.014	-0.008
	(0.059)	(0.059)	(0.027)	(0.030)	(0.040)
All controls	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348
R^2	0.418	0.328	0.265	0.340	0.407
Panel C: with lowest discriminatory auction winning bids					
Discriminatory auction	-0.027	-0.042	-0.036	-0.047	-0.060*
	(0.059)	(0.045)	(0.033)	(0.039)	(0.033)
All controls	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348
R^2	0.417	0.325	0.260	0.336	0.403

Effect on the distribution of bids

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	Quantile				
	0.15	0.25	0.50	0.75	0.85
Panel A: with weighted averages of discriminatory auction winning bids					
Discriminatory auction	-0.008	-0.051	-0.037	-0.029	-0.030
	(0.060)	(0.053)	(0.032)	(0.030)	(0.035)
All controls	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348
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Discriminatory auction	0.014	-0.016	-0.011	-0.014	-0.008
	(0.059)	(0.059)	(0.027)	(0.030)	(0.040)
All controls	Yes	Yes	Yes	Yes	Yes
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R^2	0.418	0.328	0.265	0.340	0.407
Panel C: with lowest discriminatory auction winning bids					
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	(0.059)	(0.045)	(0.033)	(0.039)	(0.033)
All controls	Yes	Yes	Yes	Yes	Yes
Observations	348	348	348	348	348
R^2	0.417	0.325	0.260	0.336	0.403

Similar patterns are observed for high and low primary rates in discriminatory auctions

CDB vs. EIB

Variable	Normalized bid					
	OLS			Bayesian		
	CDB		EIB	CDB		EIB
	(1)	(2)	(3)	(4)	(5)	(6)
Discriminatory auction	0.001	-0.020	-0.008	-0.001	-0.026	0.003
	[-0.099, 0.100]	[-0.111, 0.071]	[-0.078, 0.061]	[-0.097, 0.092]	[-0.074. 0.027]	[-0.042, 0047]
Floating bond	-0.451***			-0.443		
	[-0.700, -0.202]			[-0.555, -0337]		
Auction and market controls	Yes	Yes	Yes	Yes	Yes	Yes
Institution effects	Yes	Yes	Yes	Yes	Yes	Yes
First and last week of the month	Yes	Yes	Yes	Yes	Yes	Yes
Monthly and year effects	Yes	Yes	Yes	Yes	Yes	Yes
Market drift	Yes	Yes	Yes	Yes	Yes	Yes
Observations	269	222	79	269	222	79
R^2	0.511	0.545	0.880			
Log marginal likelihood				-267.600	-165.631	-75.411

Assessing revenue equivalence

- Point estimates are not perfectly equal to zero!
- What is the exact size of the revenue gap created by the different auction formats?
- We adopt fixed-income pricing theory to our setting to compute the 'counterfactual' prices

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- We adopt fixed-income pricing theory to our setting to compute the 'counterfactual' prices

Variable	OLS			Bayesian		
	(1)	(2)	(3)	(4)	(5)	(6)
Discriminatory auction point estimate	0.006	0.008	0.001	-0.006	0.002	0.005
Total Revenue (%)	0.012	0.016	0.002	-0.012	0.004	0.010
	(-0.169, 0.192)	(-0.177, 0.212)	(-0.161, 0.164)	(-0.139, 0.114)	(-0.133, 0.154)	(-0.141, 0.104)
Change Total Revenue/Gvt of China Expendiure in 2012-2015 (%)	0.00041	0.00054	0.00007	-0.00041	0.00014	0.00034
	(-0.00572, 0.00650)	(-0.00599, 0.00718)	(-0.00546, 0.00555)	(-0.00472, 0.00386)	(-0.00451, 0.00521)	(-0.00478, 0.00352)

This table reports the economic magnitude calculated based on Table 7 estimates. Upper and lower bounds at 95% are in parentheses.

Conclusion

- We investigate a large-size auction experiment conducted by two Chinese Government Treasury security issuers to investigate whether treasury securities should be sold through uniform or discriminatory auction mechanisms
- 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.
  - Hortaçsu and McAdams (2010): switching from the discriminatory to the uniform format does not significantly increase revenue in their counter-factual simulation of Turkish Treasury auctions
  - Bonaldi, Hortaçsu, and Song (2015): "negligible" revenue difference between the discriminatory and uniform auctions in Federal Reserve's Mortgage-Backed Security auctions