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Núm. 760
2013

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Bidders' Behaviour in Government Securities Auctions: A case study for Colombia

Pamela Cardozo*

Abstract

The paper examines the bidders behaviour in the Colombian government bond auctions during 2007 for the period in which there is no uncertainty in the supply. Three main findings are presented. First, in contrast with other treasury auctions (Castellanos [2]), the market clearing price in the Colombian auctions tends to be above the price in the secondary market. I explore this phenomenon and illustrate that a key institutional detail involving a secondary sale contingent on the primary auction may explain this difference with other auctions. Second, using identifiers that allow me to follow individual bidders across auctions I analyze the determinants of the stepwise demands. I find that predetermined variables explain the number of steps (bid-points) and the quantities. However, bid prices exhibit significant unexplained variation. Third, for demands that have 3 or more bid-points, 93% of the variability is captured by a linear regression. This result is similar to what Hortaçsu finds for Turkish auctions. Theoretically there is no reason for bid-points to be nearly co-linear. At the same time, game-theoretic models of share auctions are quite difficult to implement. This pattern in demands may play an important role in developing feasible and robust estimation methods.

Keywords. Auctions, government bond markets, uniform-price auctions, discriminatory-price auctions.

JEL. D44, G18, G28.

*Email: pcardoor@banrep.gov.co. The views expressed in the paper are those of the author and do not represent those of the Banco de la Republica or its Board of Directors. I would like to thank Christopher Ferrall, my supervisor, for his comments. All the information in the paper corresponds to the applicable in 2007.

1 Introduction

Even though most governments sell their securities through auctions, our understanding of bidders' behavior in these auctions is quite limited (Hortaçsu [6]). This paper contributes to the literature by analyzing the behaviour of bidders in the Colombian government bond auctions. The approach taken here is different from the one followed by the other descriptive studies that have contributed to the knowledge of bidders' behaviour, including the analyses by Elsinger and Zulehner [4], Keloharju et al. [10], and Nyborg et al. [11] for Austria, Finland, and Sweden, respectively.[1]

All these works estimate similar regressions to analyze the effect that exogenous variables have on the behaviour of bidders, concluding that the volatility of the secondary market price of the bond being auctioned has a significant impact.[2] In my case, instead of concentrating on the exogenous variables that correlate with the bidder's behaviour, I focus on the bidder decision problem within the auction. Additionally, I analyze how an additional sale done by the government, three days after the auction, affects the behaviour of bidders.

2 Government Securities Auctions

This section describes institutional details of how governments sell their securities through auctions. Additionally, it explains two important concepts commonly used in papers that study government bond auctions: share auction and residual supply.

Before the auction begins, the government announces the amount of securities it intends to sell (the supply). When the auction opens, bidders submit a sealed demand consisting of price and quantity pairs (bid-points). The number of pairs allowed differs by country, e.g, Korea: 5 (Kang and Puller [8]), Czechoslovakia: 10 (Kastl [9]), Turkey (Hortaçsu [7]) and Colombia: unlimited (see Appendix A). In some countries, e.g. Colombia, instead of price-quantity pairs, bidders submit interest rate-quantity pairs. In those cases the bond price can be recovered from the interest rate.

When the auction closes the government sorts the bid-points from highest to lowest price and adds the quantities demanded until the supply is met—at the market clearing price. The market clearing price is thus the price where the demanded quantity equals the supply. All the submitted pairs above or at the market clearing price are winning pairs. Bidders

[1] See Appendix A for the main characteristics of the auction in these and other countries.

[2] When volatility increases, bidders reduce the price levels at which they bid, reduce quantity demanded, and increase the dispersion of their bids.

who submitted winning pairs are allocated securities from the pool and pay these to the government.

Once the equilibrium price is found governments differ in what price winners pay. In a discriminatory auction (sometimes called a pay-as-you-bid auction) bidders pay the price they offered for their winning bids, i.e. each bidder pays a different price according to their bid. In a uniform price auction, all winners pay the market clearing price. According to Brenner et al. [1], from a survey delivered to 48 countries in 2005, 24 used a discriminatory auction while 9 were using a uniform price auction. Nine countries were using both mechanisms, depending on the security being auctioned. The remaining six were using pricing rules which are neither uniform nor discriminatory.

For purposes of illustration, assume a government issues securities worth US$10,000 under an auction and there are three bidders who submit the following bidding pairs (top panel):

Example setting: Supply: $10,000. Number of bidders: 3.

Table 1: Bids (price,quantity) and Auction Outcome

Bidder 1	Bidder 2	Bidder 3
(102,1000) (101,1000) (99,1000)	(103,5000)	(102,3000) (98,3000)
Discriminatory Auction (Price, Securities Won)		
(102,10) (101,10)	(103,50)	(102,30)
Uniform Auction (Price, Securities Won)		
(101,20)	(101,50)	(101,30)

In government securities auctions, the price submitted usually corresponds to the price the bidder is willing to pay for an imaginary bond with a face value of 100.

The market clearing price for this auction is 101. Bidder 1 has two winning pairs while bidder 2 and 3 have one winning pair each. Under the discriminatory format (middle panel), bidder 1 will have to pay 102 for each of the 10 bonds (1000/100) in the first pair[3], and 101 for each of the additional 10 bonds of the second pair. Bidder 2 and bidder 3 will have to pay 103 and 102 for each of the 50 and 30 bonds they demanded, respectively. Under the uniform price format (lower panel) the three bidders will have to pay 101 for each bond they

[3]Another way of seeing this, is that for the first pair bidder 1 receives a bond with a face value of 1000 and has to pay 102% of that face value.

won: 20, 50 and 30 each bidder respectively. In this example, the government earns $10,240 under the discriminatory price and $10,100 with a uniform price.

Ex-post analysis will always show greater revenue for the seller under the discriminatory format. But some countries continue to use the uniform one since bidders behave strategically and alter their bids according to the mechanism used. Therefore, using the discriminatory format will not necessarily make the government richer.

Without loss of generality we can normalize the quantity supplied to 1 so that bids become shares. Table 2 shows the step demand function under the share framework for the example previously shown.

Table 2: Step Demand (price,share)

Bidder 1	Bidder 2	Bidder 3
(102,0.1)	(103,0.5)	(102,0.3)
(101,0.2)		(98,0.6)
(99,0.3)		

Another important concept in the study of government securities auctions is residual supply. The residual supply of a bidder is calculated by subtracting the aggregate bid function of all other bidders[4] at each price from the total supply. Figure 1 shows that the point (the black dot in the figure) where the individual step demand function (in this case Bidder 1's function) intersects the residual supply determines the market clearing price and the total quantity (the share) won by the bidder.[5]

3 The Data and the Colombian Government's Auction

3.1 The Data

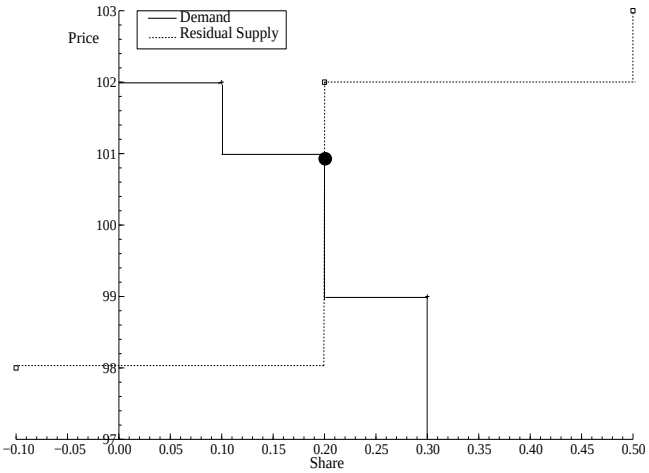
The data analyzed here covers the auctions of long term bonds—bonds with maturity of at least one year—denominated in Colombian pesos (COP)[6] held in 2007, specifically the ones

[4]In an auction with N bidders, the aggregate bid function of all other bidders is obtained by "horizontally adding" the $N-1$ individual demand functions.

[5]The intersection between the residual supply and the bidder's demand determines the total quantity won by the bidder, except, when there is more than one bidder that submitted a pair at the market clearing price.

[6]The Colombian government also auctions bonds denominated in Real Value Units (RVU: account unit which reflects the purchasing power based exclusively on the Consumer Price Index (CPI) variation), in US dollars (they have not be done since November 2001), and in COP with the coupon linked to the Colombian CPI.

Figure 1: Demand and Residual Supply of Bidder 1



without uncertainty in the supply. The sample consists of 48 auctions held between March and August 2007.[7] Auctions were held every two weeks (on Wednesdays)[8], and each time the government ran 4 simultaneous auctions. The bonds matured at the following dates with corresponding coupons in parenthesis: May 14, 2009 (8.75%), November 24, 2010 (7.5%), October 28, 2015 (8%), and July 24, 2020 (11%). All the auctions were reopenings of an existing security, therefore identical securities were traded in the secondary market both before and after the auction. A total of US$1.03 billion[9] was raised with the issue of these bonds during the sample period.

Table 3 presents summary statistics for each of the bonds. The mean coverage, ratio of total bids in an auction to the amount sold, for each bond is close to 4, meaning that on average the maximum demand is 4 times the supply. From an individual perspective, the government issued 33% in the bond with longer maturity. The longer term auctions attracted more bidders and had a higher market clearing price (MCP). Figure 2 shows that this is also the bond with the highest transaction volume during the sample period. The scarce liquidity

[7]After August 2007 there were no more auctions, because by then, the government had satisfied already its financing needs for that year. For the auctions held between January and February the government did not announce the specific supply for each bond; instead it announced a global supply to be divided by its own discretion between the group of bonds.

[8]According to the regulation [12] auctions can be held on the second and fourth Wednesday of the monetary weeks of the month. In the sample we have 12 different auction dates; for one of them the time space between auctions is 21 days.

[9]The exchange rate of August 31,2007 (2173.17 pesos/US) is used throughout the paper.

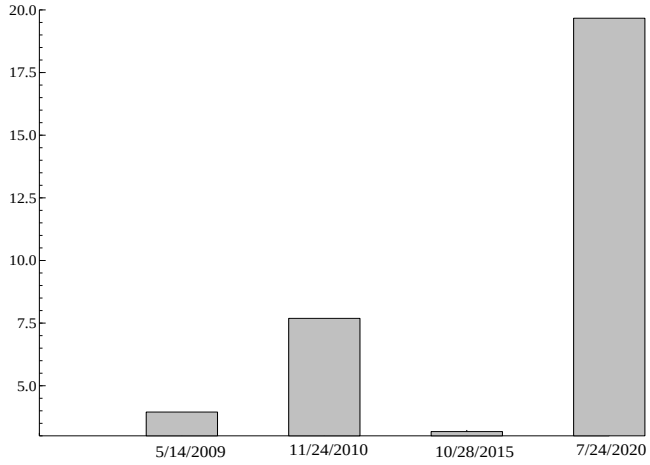
for the bond with maturity in 2015 might explain its lower price among the 4 bonds. To be able to compare prices over time, this paper presents and does all the analysis with clean prices. Clean price is the price of a bond excluding any interest that has accrued since issue or the most recent coupon payment whereas the dirty price is the price of a bond including the accrued interest. When clean prices change it is for an economic reason, therefore clean prices are more stable over time than dirty prices. Dirty prices change day to day depending on where the current date is in relation to the coupon dates, in addition to any economic reasons.

Table 3: Summary Statistics per Bond (I)

Bond	Amount Issued (US millions)[a]	MCP	Coverage			# of Bidders		
		Mean	Mean	Min	Max	Mean	Min	Max
5/14/2009	209.5	98.5	4.1	1.9	7.2	8.3	6	11
11/24/2010	251.0	93.2	3.8	2.6	6.1	10.0	8	13
10/28/2015	205.0	88.7	4.1	2.3	6.1	8.7	6	12
7/24/2020	333.5	107.8	4.1	2.7	6.3	11.6	10	13

[a]The total amount issued does not have to be equal to the money raised by the government, since the last is obtained by multiplying the amount issued and its corresponding market clearing price in percentage terms.

Figure 2: Volume Traded per Bond March-August 2007 (US billions)



3.2 The Auction of the Colombian Government

This subsection presents how the auction was conducted, its rules during the period of study, and some descriptive statistics. Appendix B presents a table with the most relevant modifications to the auction's rules from 2002 to 2007.

The day before the auction, the Central Bank of Colombia, on behalf of the government,[10] announces through an electronic system the different securities it intends to sell and their corresponding supply. The auctions for the securities are done simultaneously but from the government's perspective each auction is independent.[11]

The day of the auction bidders submit their bids electronically from 9:30 am to 10 am; bids are private, and bidders do not know how many bidders are sending bids. As discussed later, bidders do know the number of participants allowed to submit bids. The government sets the maximum quantity per bid-point equal to US$100 million[12] and the maximum difference between the highest and lowest yield per bidder in an auction to be equal to 75 basis points (b.p).[13] In the data these limits are not binding. The maximum quantity a bidder submitted was US$23 million, and the maximum dispersion in yields was 36 b.p. The minimum quantity per bid-point is COP$500 million (US$0.23 million) and is not binding either: none of the 1210 bid-points in the data set hit this lower bound.

As an example of an actual auction, Table 4 presents the bids for the six bidders that participated in the auction held on April 25, 2007 for the bond with maturity in 2015. In this auction bidders presented quantities at eleven different prices. Bidder 1 submitted four bid-points, bidder 9 three bid-points, bidder 7 two bid-points, and the other two bidders single pairs.

Table 5 summarizes the 463 bids observed in the 48 auctions in the data set. The types of bids are quite varied. While single bid pairs make up 24% of the bids, nearly the same percentage have more than 3 bid-points. The maximum number of bid-points submitted by a bidder in the data set is 9. On average the number of bid-points submitted by a bidder in an auction is 2.4.

When the auction closes at 10:00 am, the government organizes the bid-points from highest to lowest price, adds the quantities demanded, and finds the price at which the

[10] Everything related to the auction is decided by the government. The Central Bank just executes the auction.

[11] From the bidders' perspective, if they have budget constraints the simultaneous auctions might be not independent.

[12] In the regulation this quantity is set in US dollars. To obtain the maximum quantity in Colombian Pesos for each auction, the exchange rate of the auction's date has to be used.

[13] Recall that in Colombia a bid is a pair of a yield and a quantity.

Table 4: Bids Submitted by Bidders

	Quantities[a]					
Price[b]	Bidder1	Bidder4	Bidder5	Bidder7	Bidder9	Bidder12
87.823					5000	
87.772	5000					
87.721					5000	
87.681						
87.676	5000				1500	
87.671	5000					
87.620				5000		
87.570		10000		5000		
87.524	5000					
87.519			10000			
86.271						5000

[a]COP million. Auction Date: April 25,2007. Bond Auctioned: October 28 2015 (8%). The bidder's number corresponds to the id in the data set.

[b]Corresponds to the clean price the bidder is willing to pay for an imaginary bond with a face value of 100.

Table 5: Number of Bid-points Submitted by Bidders

# Bid-points	%
1	23.76
2	32.61
3	20.52
>3	23.11

supply is met. All the submitted bid-points above or at the market clearing price are winning bid-points. When there is a tie, two or more bid-points at the market clearing price, the quantities received by bidders are rationed proportionately.[14] As can be seen in Table 6, 28% of submitted bid-points were winners (at or above the market clearing price). Of these, 23% were rationed. Bidders who submitted winning bid-points are allocated securities from the pool and pay these to the government at the market clearing price (i.e. this is a uniform price auction). In the auction presented in Table 4, the supply was COP$21,835.4 million,[15]

[14]The aggregate marginal quantity demanded at the market clearing price is computed. The marginal quantity demanded at the market clearing price by a given bidder is divided by the aggregate marginal quantity demanded at the market clearing price to determine the proportion of the rationed quantity that bidder is to receive. The rationed quantity is determined by subtracting the aggregate quantity demanded at all prices strictly above the market clearing price from the final supply.

[15]In reality, the government announces the supply in cost value. For clarity, here it is presented in nominal

implying a market clearing price of COP$87.671. Bidder 1 set the market clearing price, and their pair at the market clearing price was rationed to COP$335.4 million to satisfy supply. In this case there was only one bidder at the market clearing price, hence the pro-rata rule was not used.

Table 6: Summary Statistics per Bond(II)

Bond	# of Bid-points			# of Winning Bid-points		
	Mean	Min	Max	Mean	Min	Max
5/14/2009	15.6	9	26	5.3	3	7
11/24/2010	19.0	13	25	7.3	4	12
10/28/2015	15.8	11	25	5.9	5	9
7/24/2020	25.5	20	33	9.9	6	15

The government releases the auction's results the same day the auction is held. The public announcement includes the market clearing price, the total quantity demanded and the total quantity sold. Three working days after the auction, the government might hold the non-competitive round (NCR), which the next section discusses in detail.

3.3 The Non-Competitive Round

The NCR is an additional sale of the security previously auctioned. This sale is done by the government if the coverage of the auction was at least 1.2. Only bidders that obtained bonds in the auction have the right to acquire more bonds in the NCR. The supply for the NCR is determined according to:[16]

- If the coverage of the auction was at least 2, the supply for the NCR is 80% of the auction's supply.
- If the coverage of the auction was between 1.2 and 2, the supply for the NCR is 55% of the auction's supply.

Bidders who bought bonds in the auction can buy an additional amount in the NCR in proportion to the quantity won in the auction. Roughly speaking, a bidder who acquired

value. In cost value the supply announced for this auction was COP$20,000 million. The cost value of each submitted pair is obtained by multiplying the price in percentage terms (dirty price; this paper presents everything in terms of clean prices) and the nominal value. The dirty market clearing price for this auction was 91.594.

[16]See Appendix B for its modifications from 2002 to 2007.

30% of the bonds auctioned can buy 30% of the supply in the NCR.[17] The price that bidders have to pay for the bonds demanded in the NCR is the average secondary market price of the bond on the auction date, which is calculated and published by the Colombian Securities and Stocks Exchange (CSSE, known in Colombia as BVC).[18] Between 12:30 pm and 1:00 pm of the NCR date, bidders with the right to participate submit the amount they want to purchase.[19]

From the bidder's perspective, the NCR is a sale without quantity or price uncertainty. From the government's perspective, it is a sale with quantity uncertainty since bidders can demand less than the maximum they are allowed to. Given the characteristics of the NCR, when bidders submit their bids for the original auction, they are implicitly submitting a bid to buy an European call option. This option can be exercised on the NCR date to buy the bond at the strike price—the average secondary market price for the bond on the auction date. In a market with no liquidity problems, we would only expect bidders to exercise their option if the market price of the bond on the NCR date is higher than the strike price. In this way, bidders can make profits by buying the bonds in the NCR and selling them in the secondary market at a higher price.

For the auction presented in Table 4, the coverage was 3.05, hence the government held the NCR on April 30 with a supply of COP$17468.3 million. Neither of the two bidders that had the right to attend the NCR participated. A plausible explanation is that on April 30, the bond was trading at a lower price than the one at which bidders could have obtained it in the NCR. Additionally, as shown in Figure 2, the bond with maturity in 2015 had low liquidity during the sample period: in the Colombian Electronic Negotiation System (ENS)[20], one of the two trading systems[21], there were no transactions between April 21 and May 7,2007.

According to Table 3 the Colombian government held the NCR for all the auctions—the minimum coverage was always higher than 1.2. In fact, the supply for the NCR was equal to 80% of the amount sold in the primary auction for all except one of the auctions where the coverage was 1.9. During the sample period the government issued 73.8% of the bonds

[17]The actual rules for the amount each bidder can buy in the NCR are more complicated. See Appendix B.

[18]This is the price that Colombian agents have to use to value their assets at market value. It is calculated daily.

[19]This quantity is required to be less than or equal to the maximum amount each bidder can obtained.

[20]Known in Colombia as SEN.

[21]In Colombia there are two systems of negotiations: Electronic Negotiation System (ENS), managed by the Central Bank, and Electronic Negotiation Market (ENM), managed by the CSSE.

through the auction and 26.2% in the NCR. From the bonds issued through the NCR, 9.6%, 17.9%, 24.5%, and 47.9% correspond to the bond with maturity in 2009, 2010, 2015 and 2020, respectively.

The NCR, with the characteristics explained, is a unique feature of the government of Colombia's auction. In other countries (e.g. USA, Canada, France) bidders can submit a non-competitive bid, but this is an offer sent at the same time as the competitive bids that consists of a limited amount that will be served at a price equal to the average price of the awarded competitive bids. From a bidder's perspective these types of non-competitive bids have price but not quantity uncertainty[22] and introduce uncertainty in the auction's supply. The closest case to Colombia's NCR is the one done by the Mexican government, called the buy-option round in Castellanos and Oviedo [3]. In the Mexican case bidders can buy securities at the weighted allocation price resulting from the primary auction after it takes place.[23] Further, the round is held the same day of the auction, and the non-competitive bid has quantity uncertainty because there is no guarantee that sufficient supply will be available to meet all demands.

3.4 The Bidders

In 1998 the Colombian government introduced the Market Makers program to improve government securities' liquidity in the secondary market and to promote investment in those securities. Its members, known as market makers, are the only ones that can participate in the auction.

At the beginning of each year the members of the market makers program are chosen and ranked by the government according to their participation in the auction and in the secondary market in the previous year. In the secondary market, market makers are required to quote bid and ask prices in the trading systems. These quotes must be within a specified bid ask spread. In the primary market, to be able to continue being a member of the program for the next year, the entity has to acquire a minimum of 4.25% of the securities auctioned during the current year. The NCR can be seen as a benefit that market makers receive to compensate for the risk they have to assume to fulfill their obligations.

The list of markets makers is publicly available and the entities that can participate in the program are: banks, brokers, and financial corporations. In 2007, the program had a

[22]Recall that competitive bids are price-quantity pairs. A non-competitive bid is only a quantity.

[23]In Colombia the NCR was established in 2003; before, the government held a second round which had the same characteristics as the buy option in Mexico (see Appendix B).

total of 14 members: 9 banks, 3 brokers, and 2 financial corporations.

4 Analysis and Findings

4.1 The NCR

How does the NCR affect the bidding behaviour in the auctions? As mentioned, because of the NCR, bidders are bidding to buy bonds and implicitly an European call option. This should be reflected in prices and it is indeed supported by the data as shown in Figure 3, which illustrates than in most of the auctions, the government sells the bonds at a higher price than the one observed in the secondary market. This behaviour would not make sense without the NCR. In fact, it has not been reported in other countries where typically the government sells the bonds at a lower price than the one present in the secondary market—known in the literature as underpricing (see Table 1 of Castellanos [2]). For example, in Finland according to Keloharju et al., on average government securities were underpriced by 0.041% of their face value from 1992 to 1999. On the other hand, the average overpricing in Colombia is 0.13% of face value.

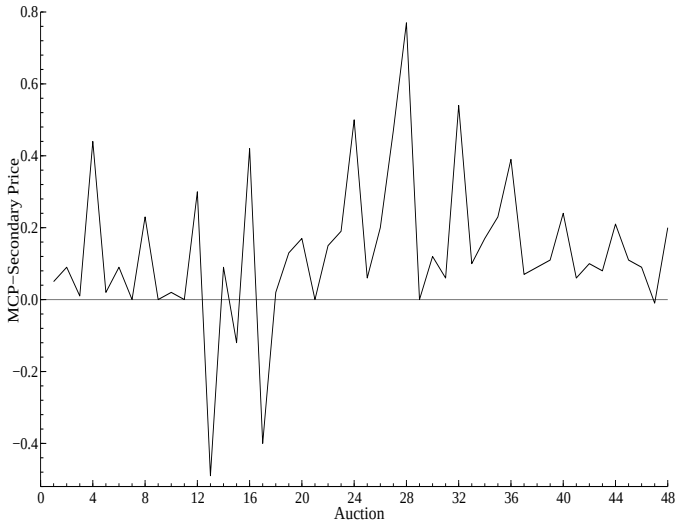
The difference between the market clearing price (MCP) and the secondary market price can be seen as a lower limit for the price of the option. Table 7 shows that this difference between prices is higher for the bonds in which bidders exercise a higher percentage of the option. This ex-post analysis illustrates that bidders incorporate the price of the option in their bidding strategy and pay more for the options which have a higher probability of being exercise.

Table 7: Difference in Prices and % Issued in the NCR

Maturity	MCP-Secondary Price	% NCR
5/14/2009	0.08	9.6
11/24/2010	0.14	17.9
10/28/2015	0.16	24.5
7/24/2020	0.37	47.9

Having mentioned that the NCR might be influencing the bidders' behaviour, another question of interest is whether the government makes or loses money by offering the NCR, in comparison to selling the bonds at the secondary market price. To consider this the following was done for each auction: i) The amount issued in the auction was multiplied by the difference between the market clearing price and the secondary market price on the day

Figure 3: Difference between Market Clearing Price(MCP) and the Secondary Market Price



Auction 1, 2, 3, and 4 corresponds to bond 5/14/2009, 11/24/2010, 10/28/2015, and 7/24/2020, respectively. The same for all the other subsequent sets of 4 auctions. The secondary market price is the mean price of the security on the day of the auction reported by ENS. For auctions 1, 7, 9, 11, 15, 21, 29, and 31, there were not transactions on ENS; the price published by CSSE for mark to market was used instead.

of the auction. A positive quantity indicates the amount of money the government is earning with respect to the market. According to Figure 3 we expect most of these quantities to be positive. ii) The amount issued in the NCR was multiplied by the difference between the price bidders have to pay in the NCR and the secondary market price on the day of the NCR. Recall that we expect bidders to exercise the option when the secondary market price is higher than the NCR's price; therefore, we expect this quantity to be negative.

Summing across auctions the government earned COP$3.36 billion. Across NCRs the government lost COP$3.60 billion with respect to the market. In net, the government's loss is COP$0.24 billion, which is 0.08% of the nominal amount issued.

4.2 The Bidders

The minimum amount that market makers have to buy in the primary market to maintain their status is typically mentioned by the market analysts and bidders as one of the aspects affecting the bidding behaviour (see Appendix C). Their argument is that bidders submit higher demands and prices in the last auctions of the year in order to satisfy this requirement. As Figure 4 and 5 illustrate, this is not what happened in 2007, as there is no marked

increase in coverage or in prices in the last auctions. Additionally, Figure 6 shows that with the exception of bidder 11 (dashed pattern), bidders maintain fairly constant the percentage of bonds obtained in the auction through time.

Figure 4: Coverage per Bond per Auction

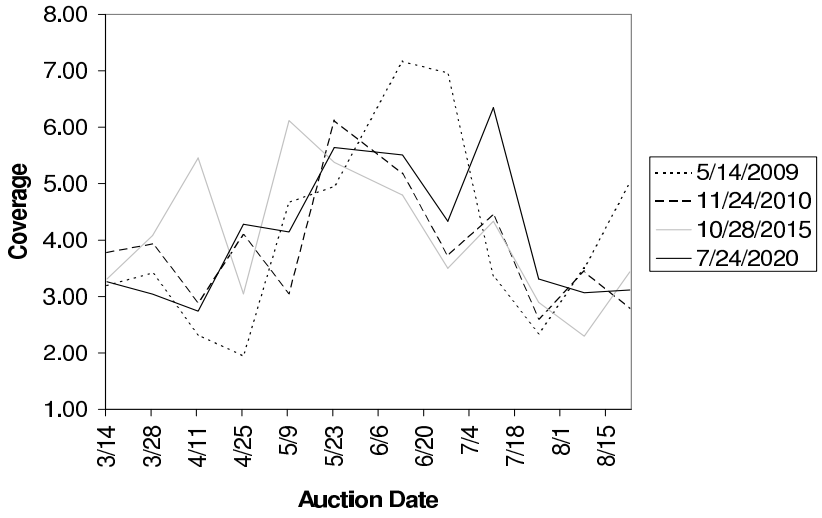


Figure 5: Market Clearing Price (clean price) per Bond per Auction

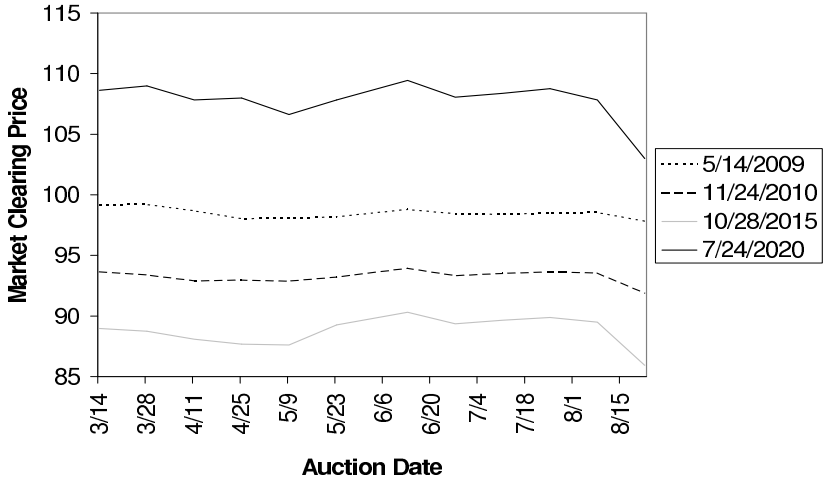
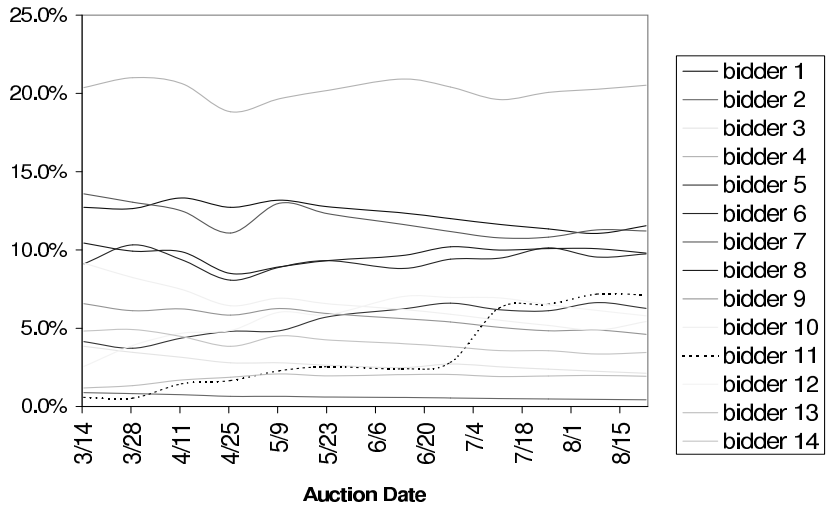


Figure 6: Percentage Obtained through the Auctions in 2007



The first observation corresponds to the percentage obtained from January through March 14.

4.2.1 The Bidders' Decisions

Every time there is an auction, bidders face the following decisions if they decide to attend: i) how many bid-points to submit, ii) how much quantity to demand at each point, and iii) how much to bid at each point. This subsection analyzes the data with respect to these decisions variables. According to interviews with some participants, their decisions are influenced by the market conditions, their businesses and their performance in the market makers program (see Appendix C). As is expected, they do not explicitly solve an optimization problem to determine their bids. However, the factors they mention as input to their decision are consistent with strategic models of bidding.

Table 8 illustrates how the entry and number of bid-points decisions vary among bidders. For the entry decision, we see that only 2 of the 14 bidders participated in all the auctions. For the number of bid points, the table shows that on average bidder 7 submits the highest number of bid-points (4.6), whereas bidder 3 submits the lowest (1.4). Additionally, the table indicates that the bidder who demands the most is not the one who wins the most and vice versa: the ratio between share demanded and share won ranges from 1.7 for bidder 6 to 180 for bidder 2. Specifically, bidder 6 demands on average almost 50% of the pool of securities and wins close to 30% of the pool, whereas bidder 2 demands 20% and ends up with 0.11%.

In most theoretical models and related structural estimation of share auctions, with

Table 8: Descriptive Statistics per Bidder

Bidder Id	# of Auctions Attended	Share Demanded[a]	Share Won[a]	# of Bid-points Submitted[a]
1	44	36.91%	12.38%	2.4
2	17	19.15%	0.11%	2.2
3	17	30.06%	1.89%	1.4
4	48	44.13%	21.80%	1.8
5	46	41.19%	8.70%	2.0
6	20	47.51%	28.54%	2.0
7	48	63.76%	9.56%	4.6
8	43	51.93%	9.97%	2.8
9	44	32.65%	3.34%	3.9
10	20	31.98%	3.21%	2.1
11	32	42.93%	16.21%	2.1
12	44	37.34%	9.11%	3.0
13	26	25.26%	3.58%	1.8
14	14	54.96%	6.62%	1.7

[a]Average per Auction.

Kastl's work as an exception, researchers have assumed that bidders submit a continuous downward sloping demand from which the researcher sees only some points. Under this view, bidders do not choose how many points to submit, neither do they explicitly decide how much to bid and for how much. Their decision is the functional form of the demand curve. Kastl [9], gets closer to reality by modeling demand as a step function where bidders choose how many points to submit.

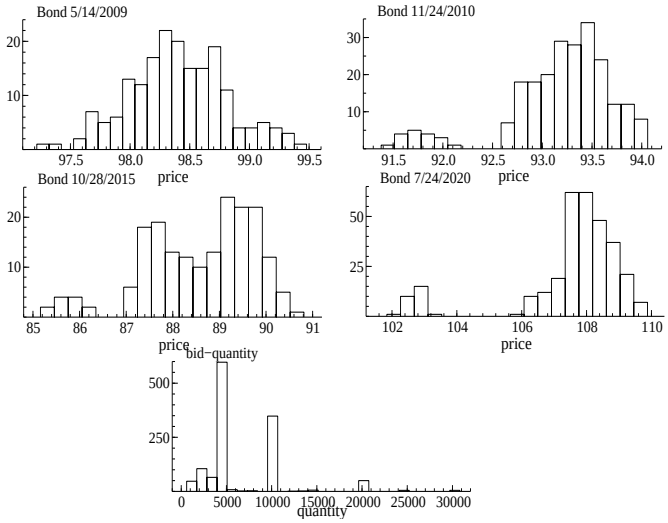
According to Kastl, if bidders behave strategically and do not face a cost for the submission of bid-points, they should submit as many points as they are allowed to. The data for Colombia shows that bidders reduce the dimensionality of the strategic space by choosing to submit a small number of bid-points—on average bidders submit 2.4 bid-points per auction. This is the same behaviour documented by Kastl for Czechoslovakia.[24]

Regarding the quantity and price decisions, for estimation purposes, Kastl assumes that bidders choose optimally how much to demand at each step (quantity-bid) but not how much to bid (price-bid). In Colombia the data shows precisely the opposite given that the variability of the bid quantities is much lower than the variability of the bid price. With respect to the decision variable quantity, the data shows that almost 80% of the bid-points

[24]To rationalize this behaviour, Kastl assumes that bidders face a submission cost.

are either for COP$5,000 million or for COP$10,000 million,[25] while with respect to price, there are just 8 cases in which the bidder submitted the same price twice—maximum number of times a price is repeated.[26] Figure 7 presents the frequency histograms for the bid prices per bond and for the bid quantity over all the bonds.

Figure 7: Frequency Histograms



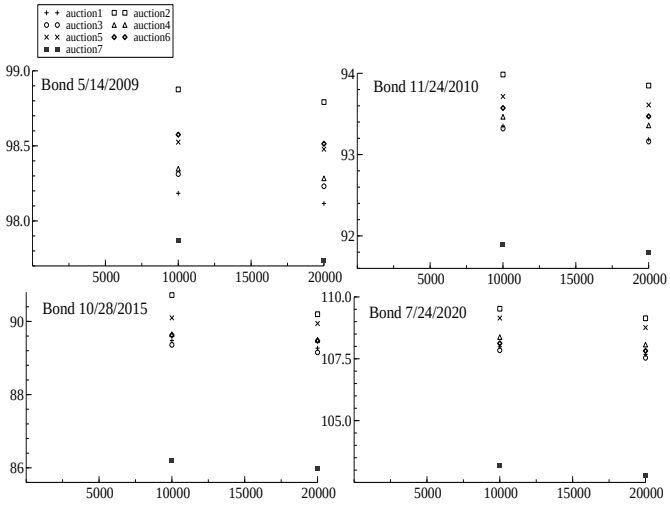
The behaviour of bidders 4 and 6 suggests that the choice variable is the price, whereas, the quantity and also the number of bid-points seem to be predefined. Bidder 4 maintained the same strategy in terms of number of bid-points and bid quantity for 3 consecutive auction dates (12 auctions), then changed it and maintained the new strategy constant—changing only the price—for 7 consecutive auction dates. For the first 3 consecutive auction dates the bidder submitted two bid-points for the bond 5/14/2009, a single bid-point for the bonds 11/24/2010 and 10/28/2015, and two for the bond 7/24/2020. For the next 7 consecutive auction dates,[27] this bidder submitted two bid-points for each of the four bonds. Figure 8 illustrates that though neither the quantities nor the number of bid-points submitted change, the prices and the slope of the line between the two bid-points do change across time. In the 10 auction dates described, this bidder submitted 74 bid-points, each of them for a quantity of COP$10,000 million.

[25] 47% of the bid quantities are for COP$5,000 million and 29% for COP$10,000 million.

[26] The comparison might be overstated because when bidders submit more than one bid-point the bid prices should be different, whereas the quantities not.

[27] From May 23, 2007 to August 22, 2007.

Figure 8: Bidder 4's Demands per Bond for 7 Consecutive Auction Dates



For the other bidder, for the 10 auction dates in which they participated, the bidder maintained a constant strategy for 6 consecutive auctions by submitting two bid-points for the bonds with shorter maturity, each bid-point for COP$10,000 million. In the sample set, this bidder submitted 39 bid-points, 38 of which were for COP$10,000 million.

4.2.2 Reducing the Dimensionality of the Bidder's Demand

Even though the previous analysis has shown that there is little variation in the quantities that bidders submit per bid-point, the study of bidders' demands is still a complex task because bidders submit step demands with different number of bid-points at different prices and shares. This was illustrated across auctions by Table 8; as Figure 9 shows it also happens within an auction. This figure shows the step demand[28] for each of the 6 bidders that attended the auction on April 25, 2007 for the bond that expires on 2015.

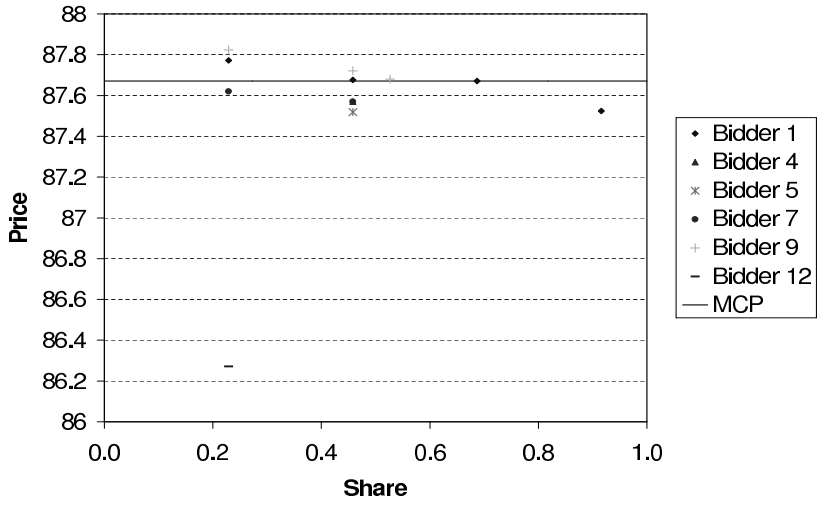
To reduce the dimensionality of the bidders' demand I estimate the following linear regression for each bidder that submitted at least 3 bid-points:

$$p_{i,j,l} = b_0 + b_1 q_{i,j,l} + \epsilon_{i,j,l} \tag{1}$$

where $p_{i,j,l}$ is the j-th price submitted by bidder i in auction l, and $q_{i,j,l}$ is the corresponding

[28]To obtain the step demand, the bid-points submitted by the bidder are sorted from highest to lowest price and the quantities are summed up. See Table (4). To present the data under the share auction framework quantities were normalized by the supply.

Figure 9: Bidders' Demands. (Auction held on April 25, 2007)



share quantity demanded at this price—not the marginal share quantity submitted. In this way, a bidder's demand is represented by an intercept and a slope, where the slope indicates how elastic is the demand with respect to the price.[29] Table 9 presents the estimation results for each of the bonds, showing that the slope of the bidders' demand ($\hat{b}_1$) differs across bonds.[30] On average bidders present more inelastic demands the longer the maturity of the bond. But, as seen in Table 3, this does not necessarily translate into higher market clearing prices.

Table 9: Linear Fit to Bidders' Demands (mean values)

Maturity	$\hat{b_0}$	St.Error $\hat{b_0}$	$\hat{b_1}$	St.Error $\hat{b_1}$	R^2
5/14/2009	1.00037	0.00023	-0.00364	0.00051	0.94160
11/24/2010	1.00100	0.00037	-0.00705	0.00119	0.93692
10/28/2015	1.00251	0.00087	-0.01167	0.00225	0.92528
7/24/2020	1.00263	0.00091	-0.02535	0.00436	0.93370
All bonds	1.00177	0.00064	-0.01193	0.00240	0.93419

Over all the bonds, 93% of the variability in the bidders' demand can be explained by the linear specification. This is similar to what Hortaçsu finds for Turkey, where the variability

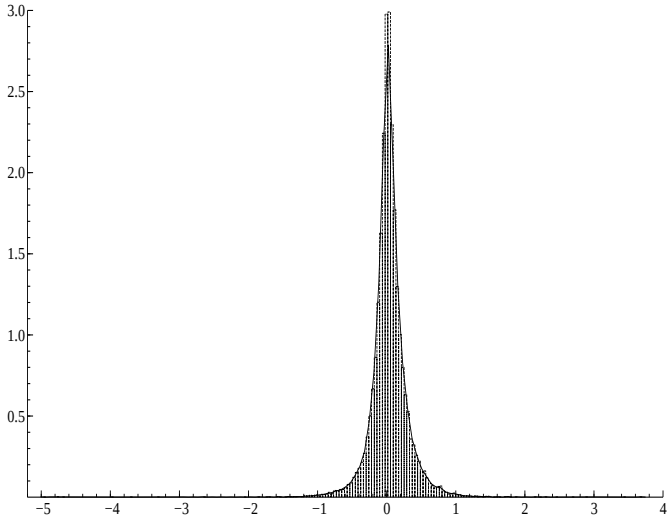
[29]To be able to compare results among the different types of bonds, prices in each auction were normalized by their corresponding market clearing price.

[30]The results show that it also differs across bidders within auctions for a given bond.

explained is 92%.[31]

As a further exercise, I estimate a linear fit for the residual supply (an intercept and a slope) for each bidder that submitted at least 3 bid-points, and intersect it with the estimated linear demand to find the market clearing price under the linearity assumption. Figure 10 displays the distribution of the difference between estimated market clearing prices and actual ones. It has a mean of 0.036 and a variance of 0.073. For this figure, given the distribution of estimated coefficients of residual supplies and demands, 100 random market clearing prices were estimated for each bidder. Though there is no apparent reason why bidders should submit a linear demand function as assumed by most of the theoretical work (e.g Wilson [15], Wang and Zender [14]), the data seems to support this assumption.

Figure 10: Density of the Difference between Estimated MCP and Actual MCP



Observations: 20,500. 4 outliers are not included.

5 Conclusion

In an auction of a single divisible object, bidders have to decide the price to bid. In government bond auctions, in contrast, bidders have to choose how many bid-points to submit, and the quantity and the price to bid for each of them. This higher dimensionality of the strategic

[31] In Hortaçsu's case, he analyzes one type of security (the 3 month bill) and his estimates are $\hat{b_0}$=0.8494 and $\hat{b_1}$=-0.0004.

space complicates the analysis of bidders' behaviour and explains why our understanding of it is far from complete.

This paper has analyzed the bidders bidding behaviour using a previously unexplored data set of the Colombian government bond auctions. Three main findings were presented and discussed: i) in contrast to results from other countries, auctions in Colombia exhibit overpricing with respect to the secondary market. The NCR was analyzed empirically and presented as a possible explanation for this, ii) bidders seem to reduce the dimensionality of the bidding space by choosing a small number of bid-points, 2.4 on average, and by choosing quantities that do not vary much—the variability of the quantities chosen is much lower than the one for the prices, and iii) for the bidders who choose 3 or more bid-points, even though their demand is a step function, the points do not deviate far from a linear function.

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Appendix A

Main Characteristics of Government Securities Auctions

Table (10) presents the main characteristics of government securities auctions across some countries, as reported by recent studies.

Table 10: Main Characteristics of Government Securities Auctions

Reference	Data Set	Sample Period[b]	# Auctions[c]	Format[a]	Bonds Maturity[d]	Coverage	# bidders[e]	# bid-points allowed	# bid-points by bidder[f]	Uncertain Supply
[3]	Mexico	01/01-04/02	180	D	short	3.24	19	∞	3.8	no
[4]	Austria	91-2006	137	D	NM[g]	2.63	NM	∞	5	no
[5]	France	01/05-12/05	49[h]	D	long	2.25	20	∞	2.9	yes[i]
[6]	Turkey	10/91-09/93	25	D	3 m.	3.57	69	∞	6.9	yes[j]
[8]	Korea	09/99-04/02	30	20 D, 10 U	3 y.	NM	25.8	5	3.1	no
[9]	Czech.	11/99-12/00	28	U	3 m.	NM	13	10	2.3	yes[k]
[10]	Finland	91-99	232	U	long	NM	8	∞	2.7	yes[l]
[11]	Sweden	90-94	400	D	short,long	2.41	12	∞	2.9	yes[m]
[13]	Germany	98-02	93	D	long	NM	42	∞	NM	yes[n]

[a] D:discriminatory, U:uniform.

[b] MM/YY

[c] Analyzed in the paper.

[d] Short term:maturity<1 year. Long term:maturity≥1 year. m:month. y: year.

[e] Mean.

[f] Mean # of bid-points submitted by bidder per auction.

[g] Not mentioned.

[h] 24 different auction's dates.

[i] Non-competitive bids are allowed and the government announces a bracket for the global supply.

[j] For the first 17 auctions the government did not preannounce the total quantity for sale.

[k] Non-competitive bids are allowed.

[l] The supply is not preannounced. In 1998 the maximum supply started to be announced.

[m] The government has the right to withdraw securities from the auction after bids have been submitted.

[n] Non-competitive bids are allowed and the government can set a % of the supply to be sold in the secondary market.

Appendix B

Modifications to the Regulation

Table 11 illustrates the main modifications to the regulation of the auction and the non-competitive round (NCR) since 2002 until 2007. The first panel, presents the main characteristics of the auction in 2002. The other panels point out the modifications. In 2002 instead of the NCR there was a second round. Their difference is that the second round was held the same day of the auction and that its demand could be higher than its supply, therefore bidders' bid for the second round had quantity uncertainty.

Appendix C

Oral Survey

This appendix summarizes the main points of an oral survey conducted in July 2008 to three market makers. The questions asked were:

1. Do you follow any type of strategy for the bidding? Which factors affect your bid?
2. When you participate in the auction do you take into account the possibility of it being followed by a NCR? Would your bids change if the NCR did not exist?
3. Before the auction, do you have a rough idea of who is going to participate in it? do you communicate with the other potential bidders to know if they are going to participate in the auction?
4. Do you consider that bidders are asymmetric?

The answers were:

1. None of the bidders follow any type of estimation. Their bids depend on: Bidder A: i) their score in the market makers program, ii) their stock of bonds, iii) the market conditions, and iv) how do they think the auction is going to be. Bidder B: i) the market conditions, ii) their score in the market makers program, iii) their utilities, depending on them they can make a risky bid that can give high returns, and iv) if they took a short position before the auction, which depends on the market's conditions. Bidder C: i) their clients, and ii) the existence of the NCR.
2. Bidder A and Bidder B: the participation decision and the bids would change if there was not NCR. Bidder C: the aggressiveness of the bids would change if there was not NCR; the NCR option can give them high profits. Their participation decision probably would not be affected, because they feel that as market makers their duty is to go the auction.
3. Bidder A: They do not communicate with the other potential bidders and do not know who is going to participate in the auction. Bidder B: They do not communicate with the other potential bidders before the auction. Sometimes, through their clients, they get some idea of who is going to participate in the auction. Bidder C: They assume that all the potential bidders are going because that is their duty as members of the program of market makers.

4. Bidder A: Yes. Bidder B: Yes. They will divide the bidders in three groups. One for the bidders that go always with high demands. Another one for the bidders that take a moderate position—like them—sending constant bids through all the auctions. They try to get 15% of the supply in each auction. And a last group for the bidders that go just when they see a clear opportunity for earning profits. They consider that the bidders in this group are playing a risky strategy because at the end of the year they might have to buy bonds at any price to satisfy the requirement of the market makers program in which members have to buy at least 4.25% of the primary auction. Bidder C: Yes. There are 2 aggressive bidders. The others can be grouped in one group.

Table 11: Main Modifications to the Auction and the NCR, 2002-2007

Year	Regulation
January 2002	
Auction[a] (10-11 a.m)	
Maximum Bid	US$ 175 million
Supply	In November, instead of a supply for each bond, the government starts to announce a global supply for all the bonds that are auctioned simultaneously but independently. The only connection between the auctions is the global supply.
Settlement Date	2 working days after the auction
Second Round	
Date	Auction's date (3-4 p.m)
Supply (supply2^{SR})	- Auction's coverage $\geq 2 \rightarrow$ supply2^{SR} = 0.5*supply1 - $1.2 \leq$ A. coverage $< 2 \rightarrow$ supply2^{SR} = 0.25*supply1 - A. coverage $< 1.2 \rightarrow$ supply2^{SR} = 0
Price	Auction's market clearing price
Participants	Market makers[b] who were able to buy in the auction
Maximum bid	supply2^{SR}
Allocation Rule	If demand > supply2^{SR}, the market marker who won the greatest amount in the auction will get his bid, then the second market market maker and so on.
Settlement Date	Same as auction's settlement date
January 2003	
Second Round: last year it was held	
Non-Competitive Round	
Date	Auction's settlement date (12:30-1:00 p.m)
Supply[c] (supply2)	- A. coverage $\geq 2 \rightarrow$ supply2 = 0.5*supply1 - $1.2 \leq$ A. coverage $< 2 \rightarrow$ supply2 = 0.25*supply1 - A. coverage $< 1.2 \rightarrow$ supply2 = 0
Price	Auction's market clearing price
Participants	Top 9 ranked market markers who won in the auction and did not go to the second round
Maximum bid	% of supply2. The % is the same as the % won in the auction
Settlement Date	Same as auction's settlement date

[a]The auction's supply per bond—not the global supply—is denoted by supply1.

[b]The members of the market makers program are divided between market makers and aspirants to market makers. In the paper this distinction was not made—all members of the program were called market makers.

[c]Because of the transition between the second round and the NCR, the supply for the NCR is supply2 minus the allocation in the second round.

Year	Regulation
August 2005	
Auction (9:30-10:00 a.m)	
Maximum Bid	US$ 100 million
Settlement Date	Same day as the auction
Non-Competitive Round	
Participants	Market makers who won in the auction
Maximum bid	% of supply2. The % is the same as the % won in the auction (for this the aspirants to market makers are not taken into account).
Settlement Date	The day of the NCR, which is the third working day after the auction
January 2006	
Non-Competitive Round	
Supply	- A. coverage $\geq 2 \rightarrow$ supply2 = 0.65*supply1 - $1.2 \leq$ A. coverage $< 2 \rightarrow$ supply2 = 0.4*supply1 - A. coverage $<1.2 \rightarrow$ supply2 = 0
Participants	Market makers (MM) and aspirants to market makers (AMM) who won in the auction
Maximum bid (allocation)	- A first amount to MM: 0.5*supply1 if A. coverage ≥ 2, or 0.25*supply1 if $1.2 \leq$ A. coverage < 2. Once this amount is defined, the amount that corresponds to each MM is proportional to what they won in the auction (excluding AMM). - The second amount is 0.1*supply1 and is distributed between the MM and AMM that are in the top 5 positions of the MM program for the current year, according to the amount that was awarded to them in the auction. - The third amount is 0.05*supply1 and is distributed between the MM and AMM that are in the positions 6 to 10 of the program, according to the amount that was awarded to them in the auction.
Price	Average market price of the auction's date
January 2007	
Auction	
Supply	In March, instead of the global supply the government comes back to announce the supply per bond.

Non-Competitive Round	
Supply	- A. coverage $\geq 2 \rightarrow$ supply2 = 0.8*supply1 - $1.2 \leq$ A. coverage $< 2 \rightarrow$ supply2 = 0.55*supply1 - A. coverage $< 1.2 \rightarrow$ supply2 = 0
Maximum bid (allocation)	- A first amount to MM: 0.5*supply1 if A. coverage ≥ 2, or 0.25*supply1 if $1.2 \leq$ A. coverage < 2. Once this amount is defined the amount that corresponds to each MM is proportional to what they won in the auction (excluding AMM). - The second amount is 0.2*supply1 and is distributed between the MM and AMM that are in the top 5 positions of the MM program for the current year, according to the amount that was awarded to them in the auction - The third amount is 0.1*supply1 and is distributed between the MM and AMM that are in the positions 6 to 10 of the program, according to the amount that was awarded to them in the auction