Sovereign Debt Auctions In Turbulent Times

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Emerging economies frequently face turbulent periods with high and volatile sovereign bond yields (e.g. Aguiar et al. (2016)). How does the way governments sell bonds in primary markets determine these outcomes? Milton Friedman was a fierce proponent of uniform-price auctions for Treasury securities. He argued that the lack of a winner's curse in such auctions would foster participation and encourage more aggressive bidding.[1] Yet many countries, in particular emerging economies, use discriminatory ("pay as you bid") auctions to sell sovereign bonds.[2] What explains these choices?

In multi-unit discriminatory auctions, bids are executed at the bid price in descending order of prices. As long as there is some bid price dispersion, some bidders pay more than the lowest accepted price (the *marginal price*) for some accepted bids. While this induces bidders to shade their bids ex-ante (thereby lowering average prices), we argue that the ability to execute some bids above the marginal price can raise government revenues in particularly poor states of the world where risk-averse investors participate because they earn high infra-marginal risk premia. This *insurance benefit* of discriminatory auctions may be particularly valuable for volatile emerging economies.

Dispersion in bid prices may arise because of asymmetric information about fundamental bond values or because bidders are uncertain about other demand and supply shocks affecting bond markets. In Cole, Neuhann and Ordonez (2021) we use detailed bid-level data from weekly auctions of Mexican short-term sovereign bonds (Cetes) to argue that asymmetric information about default is particularly important determinant of bidding behavior. However, data with such granular bid-level information is available only for a relatively tranquil period starting in June of 2001. What is the role of asymmetric information during turbulent times?

In this paper we extend the sample to December 1995, the date at which Mexico began selling Cetes using discriminatory auctions. Relative to the later sample, we cannot observe who submitted each bid, but we can still compute *overpayment* (the quantity-weighted average price paid divided by the marginal price). We analyze the data using a model of multi-unit discriminatory auctions with risk averse bidders and asymmetric information about the bond's common value. We find that the insurance benefit of discriminatory auctions is substantial: Mexico had to pay 1 p.p. lower yield during the 1998-99 crisis compared to a counterfactual with full information.

While the absence of bidder identifiers prevents us from ruling out the alternative that overpayment during turbulent times is generated by demand or supply shocks, we estimate that such shocks would have had to very large to account for our findings.

I. Data

We study data from primary markets for Mexican Federal Treasury Bills (*Cetes*). These are domestically denominated zero-coupon bonds with maturities not exceeding one year that constitute a major source of funding for the Mexican government. We focus on 28-day Cetes, which are auctioned weekly by the Bank of Mexico (almost always on Tuesdays at 10am).[3] From December 1995 to September 2017, they were sold using a discriminatory-price protocol.

Figure I plots marginal auction prices during our sample period. The sample period can

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[1] Goldstein (1962) describes Friedman's original proposal in hearings before the Joint Economic Committee, 86th Congress, 1st Session, Washington, D.C. (October 30, 1959, 3023-3026).

[2] Brenner, Galai and Sade (2009) survey the auction protocols used in middle and high income countries around the world.

[3] Cole, Neuhann and Ordonez (2021) provides a detailed overview of the market structure and institutional details.

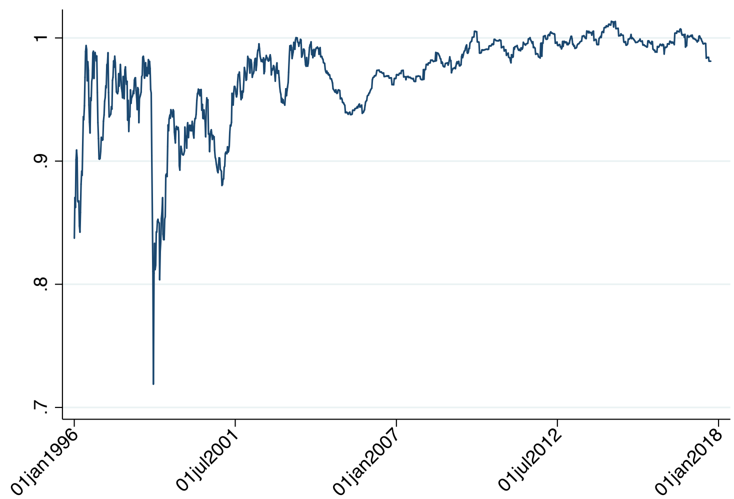

FIGURE 1. MARGINAL PRICES AT AUCTION OF 30-DAY CETES BONDS

Note: Lowest accepted price at each week's auction, computed using the annual yield deflated by yearly CPI inflation centered around the auction's month. We plot marginal prices for 1,129 auctions.
Source: Own calculations based on data from the Bank of Mexico.

be split into a *turbulent* period during the first part of the sample, and more *tranquil* period afterwards, with a sharp *crisis* happening during the turbulent period. This crisis coincided with Mexican exposure to several external shocks during late 1998 and early 1999.[4] Table 1 formally defines these periods and shows the mean and conditional standard deviation of marginal prices in each period. Marginal prices are low on average during the turbulent period, with high unconditional volatility but some persistence across auctions.

While marginal prices affect the level and volatility of bond yields, in multi-unit discriminatory auctions revenues are determined by the quantity-weighted average price paid. We use our bid-level information to compute the average *overpayment* for each auction, defined as the average price divided by the marginal price. Table 1 shows that the extent of overpayment was particularly large during the crisis.

In all periods, overpayment is negatively correlated with the *unexpected change* in the marginal price, defined using the difference between the actual price and the expected price from a predictive regression using previous prices (see the last column in Table 1). This means that some investors submit relatively more high-price bids even in auctions where marginal prices were expected to be low conditional on publicly available information. This points towards an insurance force that stabilizes government's revenues during times of distress.

In the following, we explore the determinants of overpayment using the model of discriminatory auctions with asymmetric information about common values from Cole, Neuhann and Ordonez (2021), modified to remove supply shocks and secondary markets, and quantitatively assess the insurance benefit delivered by the discriminatory auction protocol.

II. Model

Environment: There is a single period and a single good. The economy is populated by a government with exogenous funding need D and a measure one of risk-averse investors.[5] The

[4]First, the Asian crises that started in 1997 and continued into 1998 induced large capital outflows from Mexico and many other emerging economies. Second, the price of oil dropped in 1998, negatively impacting Mexican public finances. Finally, Russia defaulted on its debt and devalued the ruble on August 17, 1998, generating concerns about the sustainability of sovereign debt in countries like Mexico. See details in Vargas (1999).

[5]In Cole, Neuhann and Ordonez (2021) we verify that price-taking behavior as in a large auction is a good approximation to bidding behavior in Cetes auctions.

TABLE 1—TRANQUIL, TURBULENT AND CRISIS TIMES.

	Period	Marginal Price		Overpricing	
		Average	Cond. s.d.	Avg. (%)	Corr. w/ MP
Tranquil	01/2005 - 09/2017	0.986	0.002	0.04	-0.09
Turbulent	12/1995 - 12/2004	0.953	0.010	0.13	-0.07
Crisis	09/1998 - 02/1999	0.837	0.032	0.39	-0.10

Note: The conditional standard deviation is the variance of the predicted marginal price from a regression on the lagged marginal price. Overpricing is the ratio of average price to marginal price.
Source: Own calculations based on data from the Bank of Mexico.

government raises funds at the beginning of the period by selling at auction multiple units of a bond that promises repayment at the end of the period. Investors have wealth W at the beginning of the period but consume at the end of the period. They can invest in either a risk-free asset (storage) or the bond offered by the government.

The bond is risky because the government may default, in which case investors cannot recover any of their investment. The default probability κ_θ is random and determined by an exogenous state of the world $\theta \in \{g,b\}$, with $\kappa_g < \kappa_b$. The ex-ante probability of the good state is $f(g) \in (0,1)$; so the unconditional default probability is $\bar{\kappa} = f(g)\kappa_g + (1-f(g))\kappa_b$. Since the default probability determines the expected value of the bond, we refer to the realization of κ as the bond's *quality*. A fraction n of investors is exogenously *informed* (I) about quality, the rest is *uninformed* (U). This is the only source of heterogeneity among investors.[6]

Sovereign Auction: The government sells bonds via a pay-your-bid auction protocol (a discriminatory-price auction). A *bid* is a pair $\{P,B\}$ representing a commitment to purchase $B \geq 0$ units of the bond at a price P, should the government decide to accept the bid. Each investor is free to submit as many bids as desired. The government treats each bid independently and accepts bids in descending order of prices until it raises D in revenue.

The *marginal price* P_θ in state θ is the lowest accepted price in that state. All bids at prices above the marginal price are accepted, all bids below are rejected. Since investors have rational expectations with respect to the set of possible marginal prices, we can restrict attention to bidding strategies that assign bids of zero to prices that are not marginal in at least one state.

Investors' Portfolio Problem: Informed investors know the realization of θ, so they only submit bids at P_θ. Uninformed investors, however, may decide to submit bids at both P_g and P_b. When the bond is good, only bids at P_g are accepted; when the bond is bad, all bids are accepted. The total quantity of bonds purchased and the corresponding expenditures by informed investors in each state are

$$\mathscr{B}^I(\theta) = B^I_\theta \quad \texttt{and} \quad X^I(\theta) = P_\theta B^I_\theta$$

For uninformed investors in the good state

$$\mathscr{B}^U(g) = B^U_g \quad \texttt{and} \quad X^U(g) = P_g B^U_g$$

and in the bad state

$$\mathscr{B}^U(b) = B^U_g + B^U_b \quad \texttt{and} \quad X^U(b) = P_g B^U_g + P_b B^U_b .$$

Investment in the risk-free asset by each investor type $i \in \{I,U\}$ in each state θ is the residual $w^i(\theta) = W - X^i(\theta)$.

The critical asymmetry between informed and uninformed investors appears in the bad state (i.e, between $X^I(b)$ and $X^U(b)$). If the uninformed submit bids at P_g, they overspend in the bad state relative to informed investors, given a fixed number of bonds. Investor i's expected utility given the investor's information set $\mathscr{F}^i$ is

$$V^i\left(B^i_\theta\right) = E_\theta\left[\kappa_\theta U\left(w^i(\theta)\right) + (1-\kappa_\theta)U\left(w^i(\theta) + \mathscr{B}^i(\theta)\right) \middle| \mathscr{F}^i\right].$$

The *decision problem* is to choose B^i_g and B^i_b to maximize $V^i\left(B^i_\theta\right)$ subject to non-negativity and

[6] In Cole, Neuhann and Ordonez (2020) we consider endogenous information acquisition with auctions in multiple countries and show that discriminatory auctions can induce asymmetric information in other countries during turbulent times.

borrowing constraints ($B^i_\theta \geq 0$ and $w^i(\theta) \geq 0$). The *auction-clearing condition* that guarantees that the government raises revenue D in state θ, given share n of informed investors, is

$$D = nX^I(\theta) + (1-n)X^U(\theta).$$

Equilibrium: An equilibrium is a price schedule $P : \theta \rightarrow [0,1]$ and bidding strategies $B^i_\theta : \mathscr{F}^i \rightarrow R_+^{\mathscr{F}^i}$ such that, given the price schedule, bidding strategies solve the decision problem for all types i and the auction-clearing condition is satisfied for all θ.

Mechanism: Informed investors face a standard portfolio problem because they know the marginal price. Hence overpayment is driven by uninformed investors whose bids at P_g are accepted even when the marginal price is P_b. Two mechanisms discourage these investors from bidding at high prices. First, a high price difference $P_g - P_b$ implies more overpayment for bad bonds, depressing bids through a *winner's curse effect*. Second, a higher P_g (a lower risk premium in the good state) makes the risk-free bond a closer substitute for the high quality bond. This reduces incentives to face the risk of overpayment, a *substitution effect*.

Taken together, uninformed investors continue bidding at high prices (and thus overpay if the bad state is realized) if the winner's curse and the substitution effect are weak. We have shown that there is more overpayment in turbulent times. This is consistent with a lower substitution effect (lower average prices), but not with a stronger winner's curse (larger conditional volatility of prices). The economic mechanism is that uninformed investors are willing to bid at high prices as long as the benefits of participating at auction are large enough. In multi-unit auctions with risk averse bidders, this can occur when average default risk is high because bonds are priced on the margin, leading to a higher *infra-marginal risk premium*.

In the next section, we conduct a quantitative exploration to capture this trade-off and measure how much bond prices would have declined in the crisis had all investors been informed.

III. Calibration

In Cole, Neuhann and Ordonez (2021) we exploit detailed data with bidders identifiers to show that, in the tranquil period, uninformed investors did not overpay relative to informed investors, and that all overpricing was explained by demand and supply shocks. That is, detailed bidding data allowed us to distinguish between overpricing due to asymmetric information about default risk and other shocks.[7]

Given that bidder identities are not observable in the turbulent and crisis periods, our approach here is measure the degree of overpricing that is quantitatively consistent with the model if there is asymmetric information about default risk only, and then measure how large other non-fundamental shocks would have had to be generate the same degree of overpricing and insurance.

The model at hand has three key parameters: the default probabilities κ_g and κ_b and the probability of the high state $f(g)$. We separately calibrate these parameters to match the three main moments for the turbulent and crisis periods in Table 1: (i) average marginal prices, (ii) their conditional standard deviation, and (iii) average overpayment. The results are in the first three columns of Table 2. The table also shows the implied marginal prices and the extent to which uninformed investors overpay. 24% of uninformed bids are subject to overpayment in the bad state during turbulent times (18% during crisis).

To gauge the insurance benefits of overpayment by the uninformed, we then compute marginal prices in a counterfactual in which all investors are informed about default risk but all other parameters are held fixed. In this counterfactual there is no overpricing because all bids are submitted at the correct marginal price. The high marginal price P_g increases in the counterfactual because investors are not deterred by the winner's curse. The low marginal price P_b is slightly lower because no bids are executed at P_g (see last two columns in Table 2).

Implications for revenues depend on *average* prices. We find that the Mexican government would have paid 0.3 p.p. more in real annualized yields in the bad state during turbulent times, and 1 p.p. more during the crisis, had all investors been informed. The cost of this "insurance" is that, on average, the government would

[7] Indeed, we use this identification to claim that fears of a rare disaster (not present on path in the tranquil regime) could have discouraged uninformed investors from bidding at high prices.

TABLE 2—CALIBRATION AND COUNTERFACTUAL

A. Benchmark Model with Bond Quality shocks.								
Period	Calibration			Asym. Information			Full Information	
	κ_g	κ_b	$f(g)$	P_g	P_b	$\frac{B_g^U}{B_g^U+B_b^U}$	P_g	P_b
Turbulent	0.022	0.046	0.56	0.961	0.942	0.24	0.972	0.942
Crisis	0.074	0.157	0.53	0.867	0.804	0.18	0.907	0.803

B. Alternative Model with Non-fundamental Shocks.								
Period	Calibration			Equilibrium Outcomes				
	κ_g	κ_b	$\bar{\psi}$	$P_{g,1}$	$P_{g,\bar{\psi}}$	$P_{b,1}$	$P_{b,\bar{\psi}}$	$E_\theta\left[\frac{B_{\theta,1}}{B_{\theta,1}+B_{\theta,\bar{\psi}}}\right]$
Turbulent	0.026	0.039	1.70	0.964	0.961	0.946	0.941	0.59
Crisis	0.096	0.141	1.48	0.872	0.864	0.812	0.800	0.68

Note: In Panel A, $n = 0.4$ and $D/W = 0.2$ (as calibrated in Cole, Neuhann and Ordonez (2021)). In Panel B, $f(g) = 0.5$ and $Pr(\bar{\psi}) = 0.5$.

have paid 0.5 p.p. less during turbulent times and 2.2 p.p less during the crisis period.

A. *Adding non-fundamental shocks*

To assess the relevance of other, non-fundamental, shocks in explaining the observed overpricing, we redo the calibration assuming $n = 1$ (all investors know the risk of default) and a supply shock (i.e. $D\psi$ with $\psi = \{1, \bar{\psi}\}$) that is unknown to all investors. We calibrate $\bar{\psi}$ to target the mean and conditional variance of marginal prices and overpricing. The results are in panel B of Table 2. We also report equilibrium marginal prices (two per state), and the average overbidding across both states.We find that overpricing can be rationalized by a supply shock of 50% in the crisis and 70% in turbulent times.

This can be equivalently expressed in terms of a demand shock, whereby only a fraction $\eta = \frac{1}{\psi}$ of investors participate in the auction. The implied demand shock is 32% ($\eta \in \{1, 0.68\}$) in the crisis and 42% in turbulent times. While we cannot directly estimate such shocks, we can use the number of bidders to proxy for demand shocks. The coefficient of variation *in the tranquil period* (the only period where we have this information) is only 0.09, compared to the imputed 0.26 during crises and 0.37 during turbulent times.[8] Under this interpretation, the insurance mechanism now works to protect the government against demand shocks.

[8]Supply shocks are likely to be small given how many bonds the government sells is publicly announced before the auction.

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