Texas CD Auctions

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- **CD Auctions in Texas** follow a mechanism very close to a **one sided limit order market** *(so is more amenable to analysis)*.
- A certificate of deposit (CD) is a fixed rate short term loan.
- In Texas (and several other states) the state government auctions CDs to provide liquidity for banks' lending operations:
    - The loans are for several months (six).
    - The auctions are held once a month and last 30 minutes.
    - There is an upper bound on total available funds at each auction (usually $80 million).
    - Banks can bid for as little as $100,000 and as much as $7 million.
    - Consequently multiple banks win CDs at each auction.

- Prior to bidding the auctioneer (state government) sets:
  - a reservation interest rate (lower than commercial rates available nationally)
- During the auction banks (bidders):
  - cannot withdraw a bid but can be increase it throughout the auction.
  - can increase their bids as many times as they like by any amount.
- Funds are allocated to banks offering the highest interest rates.
  - Winning banks pay the highest (most recent) interest rate they bid.
  - Losing banks pay nothing.
- Very little information is provided to banks during the auction.
  - The ONM rate is the lowest bid to win a CD if bidding stops.
  - When a bank bids the only information is receives is whether their bid is less than the ONM.

The Data
The sample

- Our data set contains 78 auctions from 2006-2010 straddling the financial crisis of 2008.
- A pool of 73 potential banks bid over this period with an average of 24.5 banks entering each auction.
- Averaging across auctions, 72% of banks win.
- Money left on the table (MLT) is the dollar difference in interest payments for a winning submission and the highest losing bid.
- MLT is $624 (pre) and $1372 (post) per winning bid.
- The average national CD rate in the post-2008 period is 0.79% per annum.
- The average reserve rate between 2008 and 2010 in these auctions at 0.71% is slightly less.

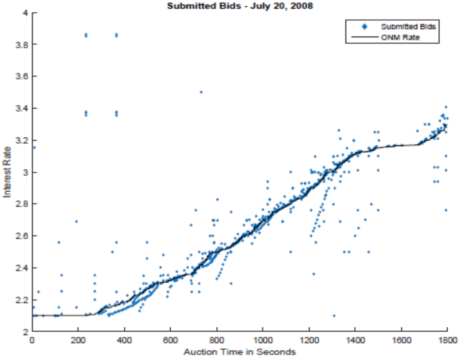
The Data

The bidding process

- At each point in the auction, if the bidding were to stop altogether:
  - ONM is the interest rate of the lowest winning bid
  - INM are higher interest rates (or bids)
  - OUT are losing bids
- As the auction progresses:
  - the lowest previous bids go stale falling OUT
  - because more higher INM bids displace older lower bids.
- This implies the ONM rate:
  - stays flat until the total quantity of bids exceeds the amount offered
  - then steadily increases throughout the remaining auction time.
- How much do banks know?
  - Banks do not directly observe other bids know the other previous
  - they only know whether their current is OUT or not.

The Data

Tracking bidding behavior in a typical auction (Figure 1 BGM 2021)

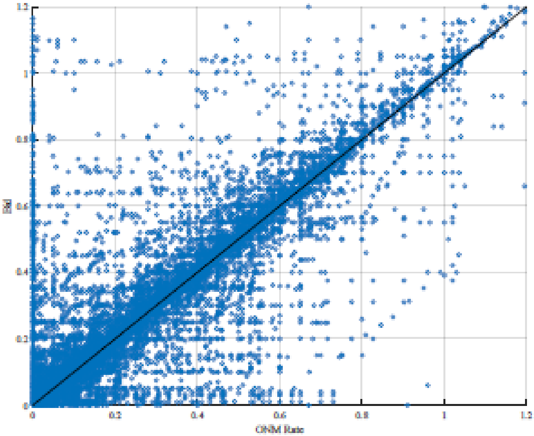


Note: The figure shows each submitted bid within one auction. Each point represents a single bid, and the solid black line is the ONM rate. The ONM rate starts at the auction reserve rate of 2.100 and increases over the course of the auction as more INM bids are placed.

- The black line is the ONM rate, and it shows how banks:
  - creep up to the ONM submitting successive bids to learn it.
  - jump bid when there is nothing more to learn right now

The Data
Figure 2(a) BGM 2021

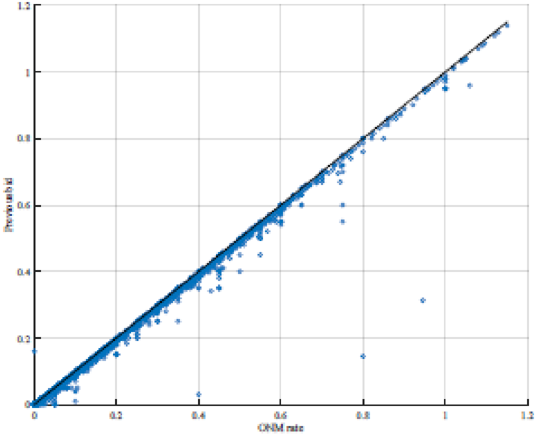
- ONM rates are shown on the horizontal axis, bids on the vertical.



Auctioning Certificates of Deposit in Texas

Figure 2(b) BGM 2021

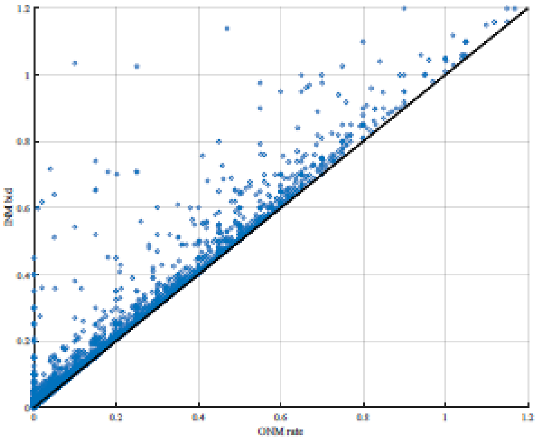
- For each ONM bid calibrated on the horizontal axis, the vertical axis plots the previous bid.



Auctioning Certificates of Deposit in Texas

Figure 2(c) BGM 2021

- For each ONM bid the vertical axis plots the next bid.



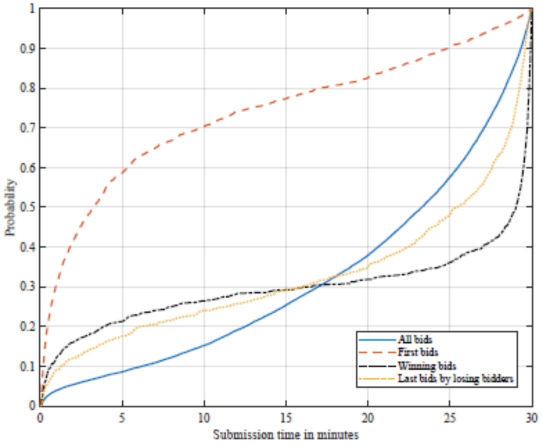
The Data

Submission times

- The next figure is the empirical distributions of submission for:
  - all bids
  - initial bids
  - winning bids
- Three other notable features of this figure are:
  1. bidding is most intense at the beginning and end of the auction
  2. there is some sniping (last seconds bids that preclude a competitive response)
  3. Many winning bids are submitted prior to the final minutes of the auction (further evidence that banks do not incrementally increase their bids).

The Data
Figure 3(a) BGM 2021

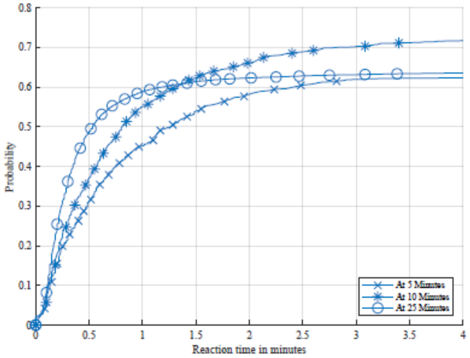
- All bids, first bids, winning bids and last bids by losing banks.
    - As the auction progresses monitoring becomes more intense.



The Data

Reaction times: Figure 3(b) BGM 2021

- How long does it take banks to respond when their INM bid falls OUT?
- The figure displays the distribution of reaction times at the 5 minute, 10 minute and 25 minute mark.



A Model

Towards a theory

- Summarizing the data:
    - The number of banks bidding is uncertain until the auction ends.
    - Bidders creep to ONM and then jump to INM
    - Bidding activity is most intense at the beginning and end of the auction.
    - Sniping (bidding in the last few seconds) is not universal.
    - Many winning bids are submitted in the early stages of the auction.
- Some pointers towards a theory:
    - Perhaps bankers balance off time demands between tracking the ONM rate and other investment opportunities.
    - They creep to check ONM and then jump to INM and then work on another activity.
    - To compute their losses from MLT we would compare the product of:
        - the margin between their borrowing and lending rates.
        - total amount of loans.

A Model

Notation for valuations

- The total gross valuation for each bank is given by:

$$\tilde{v} = xy + \underline{r}$$

where:

  - $\underline{r}$ is a reserve rate set by the interest rate on a US Treasury bond
  - y is drawn from a distribution $F_Y(\cdot)$
    - common to all banks within the auction
    - factors affecting the market for deposit funds in the state of Texas as a whole when the auction is held
  - x is a private valuation by each bank from the same distribution $F_X(\cdot)$
    - the value of the funds to that particular bank
    - such as investment opportunities in their local area.
  - the reserve rate is set exogenously and that x and y are independent.
- We assume the bank knows:
  - $\underline{r}$ and $v = xy$,
  - but not necessarily the multiplicative factors x and y.

A Model

Notation for bidding process

- **Bidding opportunities** arrive randomly over $\mathcal{T} = [0, T]$ *(length of auction)*:
  - triggered by the start of the auction and whenever a bid is pushed OUT
  - $G_t(z)$ is probability a bidding opportunity is received within z seconds of being pushed OUT at time t is denoted.
  - J is the total number of bidding opportunities, is not known until the auction is over.
  - $j \in \{1, ..., J\}$ indexes bidding opportunities
  - Denote by r_j the ONM rate when the bank receives bidding opportunity j.
- Each bidding opportunity consists of two stages.
  - Bank announces *maximal creep value* $c_j \in [0, \infty)$.
  - If $c_j \geq r_j$ bank learns r_j and is obligated to bid $b_j > r_j$
  - If $c_j < r_j$ bank drops out of auction
- In the first stage a dominant strategy is to announce $c_j = v$ *(similar to second price sealed bid auction)*.

A Model

Value function and first order condition

- If $c_j \geq r_j$ the bank bids $b_j \in (r_j, \infty)$ to solve the recursion $V(h_j, r_j, v) =$

$$\sup_{b_j} \left\{ \begin{array}{l} \left[\Pr_j(W_{b_j}) \cdot (v - b_j)\right] \quad + \\ E_j \left[\; 1\{\widetilde{W}_{b_j}\} \cdot 1\{j < J\} \cdot 1\{v > r_{j+1}\} \; \cdot \; V(h_{j+1}, r_{j+1}, v) \; \right] \end{array} \right\}$$

  where:

  - $E_j[\cdot]$ is an expectation conditional on h_j, the bank's information at j.
  - W_{b_j} the event that a bid of b_j wins the auction.
  - $\widetilde{W}_{b_j}$ is the event that a bid of b_j does not a win.

- The first-order condition for the bank's problem in our model is

$$\begin{aligned} 0 \quad = \quad & (v - b_j)\partial \Pr_j(W_{b_j}) / \partial b_j - \Pr(W_{b_j} | h_j) \\ & + \frac{\partial}{\partial b} E_j \left[\; 1\{\widetilde{W}_{b_j}\} \cdot 1\{j < J\} \cdot 1\{v > r_{j+1}\} \; \cdot \; V(h_{j+1}, r_{j+1}, v) \; \right] \end{aligned}$$

Identification and Estimation

The basis for identification

- The main barrier to using the FOC for inference:
  - Both r_j and the final ONM rate depend on what other banks do.
  - Their bids depend on v through the bank's earlier bids *(such as b_{j-1})*.
  - Therefore the bank's history, h_j, depend on (unobserved) v *(in a complicated way)*.
- Our approach exploits the events $1\{c_j < r_j\}$ and $1\{c_j \geq r_j\}$:
  - whether the bank drops out of the auction or not
  - integrating out whether it had an bidding opportunity
- This approach is more robust than imposing all the equilibrium restrictions. We:
  - apply a very weak concept of equilibrium (dominance).
  - allow the sample of auctions to be in different equilibria.
  - even let banks deviate from equilibrium in rationalizable ways.
- The limitations are that:
  - only identifies the distribution of the valuations (not pointwise).
  - is less efficient than maximum likelihood (ML).

- Let $\rho_j \in [0, T]$ denote the time the bank makes its j^{th} INM bid.
- Let $\tau_j \in \left[\rho_j, T\right]$ denote the j^{th} time the bank is pushed OUT.
- $G_t(z)$ is exogenous, easily identified and estimated in a standard way drawing upon the pairs (τ_{j-1}, τ_j)
- All information about the bank's valuation is impounded in its final bid, and comes from two components.
- The first is a lower bound on the support of the bank's valuation implied by the last (winning or losing) bid, given by $1 - F_V(r_{\rho_J})$.
- The second component, denoted by $H(F_V, G_{\tau_J})$ provides upper bounds in the event that its final bid is losing.

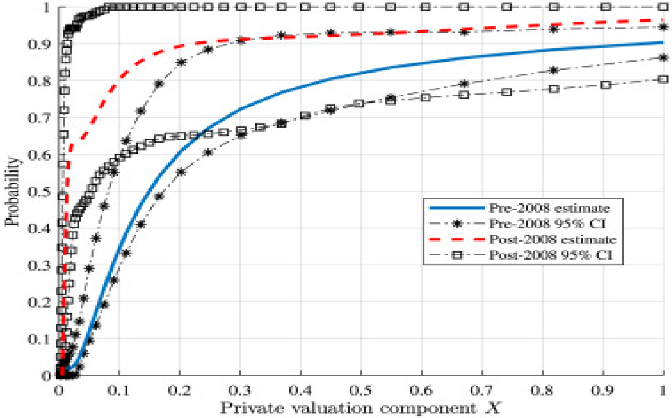
- The probability a bank never reenters the auction after being pushed out at time τ_J is::

$$H(F_V, G_{\tau_J}) \equiv (1 - G_{\tau_J}(T)) + \sum_{s=S_J}^{S} [G_{\tau_J}(t_{s+1}) - G_{\tau_J}(t_s)] \left[F_V(r_s) - F_V(r_{\rho_J})\right] \quad (1)$$

  where:
  - $r_{\rho j}$ is the ONM rate at the bank's j^{th} bidding opportunity.
  - $r_{\tau j}$ as the ONM rate that subsequently pushes j^{th} bid OUT at τ_j.
  - $1 - G_{\tau_J}(T)$, is the probability that another bidding opportunity is never received, preventing the bank from responding with another bid.
- Components in the second term of the summation are probabilities that a bidding opportunity is received between the ONM rate increments and the bank's valuation lies between the ONM rate when it last bid and the current ONM rate when the opportunity is received.

Empirical Results from Structural Estimation

Estimated distribution of private values



Empirical Results from Structural Estimation

Allocating the CDs to banks with the highest valuations

- Part of the reason auctions are commonly used is because they are supposed to provide an efficient means of allocating resources amongst competing uses.
- We estimate the efficiency loss relative to an ideal mechanism *(when there are no frictions, no rational inattention)* is about :
  - 10% prior to the 2008 financial crash
  - 2% after the financial crash
- The probability distribution of valuations is less dispersed post 2008, so mistakenly ranking a project is less likely.
- Thus an important contributing factor to the decline is that projects were easier to evaluate post 2008.

Empirical Results from Structural Estimation

Revenue consequences

- Another consideration is how much revenue the state of Texas generates from these auctions.
- Suppose it was possible to implement a uniform price auction in which there were no bidding frictions.
- Such an auction would achieve the optimal allocation.
- In addition it would have increased revenue by an estimated:
  - 8.5% pre 2008
  - 2.6% post 2008.
- Note that allocating CDs to higher valuation projects broadens the scope for extracting rent in the form of higher bids