Money Markets and Treasury Auctions with Heterogenous Bidders

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Abstract:

The purpose of this paper is to propose structural econometric methods for the empirical study of Wilson's (1979) share auction model. This is a common value model in which a single and perfectly divisible good is sold to a group of symmetric and risk-neutral buyers. The main goal is to analyze changes in bidding behavior of participants on Treasury auctions. We apply similar private-value approach designed in Hortacsu, A. and J. Kastl (2012), and applied in Elsinger, Schmidt-Dengler, Christine Zulehner (2013). The econometric model is estimated using a two-step procedure. In the first step we estimate the discrete bid value function using bootstrap similarly to N. Cassola, A. Hortacsu, J. Kastl (2007), and next we regress bid values on exogenous variables. We analyze T-bond auctions arranged by the Ministry of Finance of the Czech Republic and Czech National Bank before, during and after the spillover of the credit crunch crises in 2007 and 2008 in Europe. Most of the auction bidders (more than 75%) are foreign controlled financial institutions or foreign controlled insurance corporations and pension funds. The seller faces a tradeoff between efficiency and revenue. In equilibrium it is optimal to set a positive reservation price both from revenue and efficiency point of view. The reason is that bidders use asymmetric strategies across units in equilibrium. The positive reservation price reduces such an asymmetry. During the crisis the Czech National Bank started to use new extraordinary policy tool-facility. I design a model of the multi-unit auction of Treasury auctions and using the data on individual bidder bids (price-quantity pairs) provided by the Ministry of Finance of the Czech Republic. I compare the impact of various changes in the auction rules on the bidder behavior and the revenue collected in the auction that determines costs of state debt service of the Czech Republic.

Keywords: multi-unit auction, banking, treasury market, auction with heterogenous agents.

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INTRODUCTION

In the Czech Republic, the Ministry of Finance services the state debt by issuing Treasury securities (T-bills and T-bonds) in auctions. T-bills and T-bonds differ in many characteristics including maturity (T-bill less than a year and T-bond more than a year), coupon payment (T-bill has no coupon) and taxation method. Auctions of both types of securities are organised by CNB. While T-bills are sold in uniform-price auctions, T-bonds are sold in discriminatory-price auctions. After issuing Treasury securities on the primary market, they are further traded on the secondary market.

In a standard game theoretical analyses each bidder submits bids that maximize the bidder's payoff given the strategies of opponent bidders. But estimates of expected utility equilibrium first order conditions (FOC) in auction games are typically difficult if not impossible to evaluate even if their parametric representation has a simple functional form. The analysis of bidder best response strategies is a challenge for the auction theory (see Jackson and Swinkels (2005) for the proof of equilibrium existence). The nonparametric econometrics of auctions is discussed in Athey and Haile (2007) who analyse the strategic considerations that characterise the dealer's best response strategy. Athey and Haile (2007, section 10.1) show that in a multi-unit auction bidder's values can be econometrically identified from the submitted bid distribution.

Since the identification equation is not linear, the econometrician often uses appropriate simplifying assumptions on the bidder's value distributions to derive a representative econometric model. Nyborg and Strebulaev (2004) provide an example of such a simplified model. Similar approaches were applied in empirical studies on Finish Treasury auctions by Keloharju, Nyborg, and Rydqvist (2005) and on ECB REPO auctions by Bindseil, Nyborg, and Strebulaev (2009). Another type of empirical studies include individual level characteristics to explain submitted bids (e.g. Hamao and Jegadeesh (1998) and Silva (2003)).

There are also non-parametric estimation techniques. If one applies the Constrained Strategic Equilibrium and Simulation Monte Carlo Approach (see Armantier, Florens, and Richard (2008) and Armantier and Richard (2000)) to the auction data numerical approximation of FOC can be computed. By combining these two approaches, it is possible to produce an operational procedure for analyzing a much broader class of game theory models than that for which there exists operational analytical or numerical solutions to their extensive game representation. An application specific form of strategies is motivated by two objectives: 1) 'bounded rationality' or 'rules of thumb' behavior, 2) functional approximation of more complicated Nash equilibrium solutions. There are, alternatively, other non-parametric approaches to estimate the FOC condition using GMM (see Fevrier, Preget and Visser (2002)) that one can apply.

In our paper we will extend the model designed by Kastl (2012). We assume that there are several types of banks (indexed by c) to account bank heterogeneity. Then one can use bootstrap technique applied in Cassola, Hortacsu, and Kastl (2013) to calculate bidders' values. Finally, we will follow the approach by Elsinger, H., P. Schmidt-Dengler, Zulehner Ch. (2013) formulate hypothesis, estimate the model and test the hypothesis.

THE DATA

Our dataset was provided by the Ministry of Finance of the Czech Republic and other informational agencies and contains all bids submitted by each bidder in the Czech Treasury Bond auctions over the period from January 2005 to December 2011. For each auction, we know the submitted bid schedule of each bidder and the winning bids for each bidder. We also have information on volume and maturity of the bond.

TABLE 1 - to be inserted here.

There are descriptive statistics in Table 1 above. One can see that noncompetitive bids play a small role with less than 5% of total issue size being allocated through noncompetitive bids. We will therefore abstract from the option of submitting noncompetitive bids in the structural/reduced form model. Similar approach was used in Hortacsu, A. and J. Kastl (2012), Elsinger and Zulehner (2007), and Elsinger, Schmidt-Dengler, Christine Zulehner (2013).

Noncompetitive bids are common in treasury auctions in several countries, although the exact rules regarding allocation and timing of submission of bids vary. While they do play a minor role in the eventual allocation, the option of purchasing at the average price may affect the bidding behavior and hence bias our interpretation of results (marginal valuations, etc.).

One can be reasonably justify that banks have idiosyncratic shocks to their liquidity needs due to deposit flows and the corresponding reserve requirements. The underlying assumption we make here is that these shocks are independent conditional on observed macro, secondary market conditions and other reporting data.

Due to the limited liquidity in the secondary market for Czech T-bonds, we use additional information to approximate the secondary market. We include German government bonds that were selected to fit the characteristics, i.e., end date and maturity, of the Czech government bonds. To capture the macroeconomic conditions, we added the consumer price index and GDP growth of Czech Republic, Germany, France and Netherlands and Eurozone and the excange rate CZK/EUR. To capture bidders characteristics we use the data from monthly reporting of the Czech banks.

Since the ČNB moved from yield tenders to price auctions in 2004, we converted observed bids into annual yields using information on coupon size, coupon dates, and maturity. We will estimate the parameters in terms of yields.

Our choice of combination of French, Netherlands and German government bonds can be justified by the following consideration. As Figure 1 (source Graf III.6, CNB) reveals the 5-year government bond interest rates move together across all EU countries. The comovment of bond rates is more obvious after the introduction of the Euro until summer 2007 when the first signs of the financial markets crisis appeared. Before the introduction of the Euro we observe a convergence process showing that Czech government bond yields exhibit a similar pattern as the yields from countries such as Germany, France or the Netherlands. Thus, we believe that the use of German government bond yields is a good illustration.

THE MODEL, THEORY AND METHODS

I will model the strategic behavior of bidders in auctions for short term borrowing (i.e., REPO, T-bill and zero coupon T-bond) with maturity t. I will assume that both in the period before and after the global financial crisis break up bidders form rationally marginal value for short term funds that we denote as $v_i\left(q \mid I, II_i\right)$ where q stands for the number of units demanded in auction, I represents all the public information common for all banks (e.g. ;data), and II_i represents the private information of a specific bank (e.g. micro) at given time.

We omit the time index of all variables for simplicity. By assuming that banks behave according to a particular strategic equilibrium model of value or profit maximization, the researcher can map bidder's observed bids and bidding decisions into their unobserved marginal values. The inferences drawn from such approaches rely on the assumed strategic behavior. Then marginal value can be identified from submitted bids (price quantity pairs) given the bidders use the optimal best response equilibrium strategies in the auction by Athey and Haile (2009, see section 10.1.). An overview and comparison of various recent methodologies used by various researchers to analyze multi-unit auctions of Treasury securities is in Cardozo (2010).

Using similar arguments to Kastl (2010) one may assume that bidders do not consider ties when playing equilibrium strategies because bids are rarely rationed in the data. In his approach the seller is flexible in adjusting the number of supplied units ex-post that simplifies the analys.is.

Let me construct one period n-bank model. Risk-neutral banks compete to provide funds to the government G in exchange for T-bonds and private sector loans L. I model the problem of a profit maximizer bank that provides different services, pricing monopolistically the products where information costs are more relevant. We extend the model by Swinkels , in the spirit of Hortacsu McAdams and Elsinger, H. and P. Schmidt-Dengler, Ch. Zulehner **(2013)** : "Competition in Austrian Treasury Auctions", mimeo.

Let me construct one period n-bank model. Risk-neutral banks compete to provide funds to the government G in exchange for T-bills or T-bonds and private sector loans L. I model the problem of a profit maximizer bank that provides different services, pricing monopolistically the products where information costs are more relevant. The basic profit maximization problem of the bank is:

To analyze bidder (=bank=dealer) i"s problem, suppose that he is a producer endowed with borrowing-lending technoloy A() which uses several inputs (various types of assets and liabilities, labour and capital) to provide financial services on the loan-deposit market.

Kastl assumes that banks compete in prices but not quantities. Quantities are generated by an exogenous proces P_{Q. }Let us assume that P_{Q} is uniform on the interval [p_{min},p_{max}]. We will design the model with the following features:

- There are T discriminatory auctions indexed by $t = 1, \dots, T$. In each auction t, the seller offers S_t indivisible units for sale to N_t potential bidders.[1]
- We allow for C different groups of bidders denoted by c such that $\mathrm{N_t} = \sum_{c=1}^{C} \mathrm{N_t^c}$. Conditional on type c, bidders in each auction are symmetric and risk-neutral with independent private values.

Before the auction each bidder receives a private signal $\varphi_{i,t}$ drawn from from distribution F_c. The set of all possible signals of bidder i we will denote as Φ_i. Signals are distributed independently within and across bidder types as well as across auctions. The marginal valuation function has the form $v_i(q, \varphi_{i,t})$. The marginal valuation function is increasing in $\varphi_{i,t}$ it and weakly decreasing in q. The marginal valuation function determines the total value $TV_{i,t}$ of $q_{i,t}$ T-bonds to each bidder with signal $\varphi_{i,t}$ $\mathrm{TV_i}(\mathrm{q_{i,t}}, \varphi_{i,t}) = \int_0^{\mathrm{q_{i,t}}} \mathrm{v_i}(\mathrm{q}, \varphi_{i,t}) \mathrm{dq}$

Bidders are required to submit several bid-quantity pairs that specify what they are willing to buy in the auction T-bonds. Namely, we assume that each bidder i's strategy space S_i consists of a triples $\langle b_{i,t}, Q_{i,t}, K_{i,t} \rangle$ where $b_{i,t}$ and $Q_{i,t}$ are non-negative vectors of dimension $K_{i,t}$ and $K_{i,t}$ is a natural number. Moreover we restrict the bidders to sort bid-quantity pairs according to bids; i.e. $b_{i,j,t} \geq b_{i,j+1,t}$ for $j = 1, \cdots, K_{i,t}$.[2] For each bidder we denote the vector of cumulative quantities as $q_{i,t}$ where $q_{i,j,t} = \sum_{k=1}^{j} Q_{i,j,t}$ for $j = 1, \cdots, K_{i,t}$ and for technical reasons we define also $b_{i,0,t} = \infty$ and $q_{i,0,t} = 0$ and $b_{i,K_{i,t}+1,t} = 0$ and $q_{i,K_{i,t}+1} = \infty$. Then one can easily construct a stepwise demand and inverse demand curves of bidder i whose private signal is $\varphi_{i,t}$

$$\mathrm{y_{i,t}}(\mathrm{p}|\varphi_{i,t}) = \mathrm{q_{i,j}} \text{ if } \mathrm{p} \in [\mathrm{b_{i,j}}, \mathrm{b_{i,j-1}}) \text{ for } \mathrm{p} \in [0, \infty) \qquad (1)$$

$$\mathrm{y}_{\mathrm{i,t}}^{-1}(\mathrm{q}|\varphi_{i,t}) = \mathrm{b_{i,j}} \text{ if } \mathrm{q} \in (\mathrm{q_{i,j}}, \mathrm{q_{i,j+1}}] \text{ for } \mathrm{q} \in [0, \infty) \qquad (2)$$

[1] We will use he to represent the seller or auctioneer and she to represent the bidder.

[2] Since the seller orders the price quantity pairs according to bids after collecting the bids this restriction has no effect on the auction game up to the permutation of the price-quantity pairs.

Each bidder is restricted to buy at most $\bar{Q}_{i,t}$ T-bonds in an auction at time t. Therefore bidders has no incentive to submit such a quantity vector that $q_{i,K_{i,t}} > \bar{Q}_{i,t}$.[3]

The Game. Before the auction the seller nnounces the number of T-bonds offered for sale O_t and a reservation price R_t where $R_t \in [0, \infty)$. Each bidder i submits a non-increasing step function. This function specifies how much a bidder of type $\varphi_{i,t}$ demands at price p. We make two additional assumptions consistent with the auction procedure. First, we assume that whenever there price clearing the market is not unique, the seller uses the most favorable price from her perspective. Second, bids at the lowest price accepted (stop-out-price) may be subject to pro rata curtailments to sell the scheduled issue size. Therefore the quantity the bidder i wins $\tilde{q}_{i,t}$, depends on the submitted bid-quantity pairs of all bidders $\langle b_{i,t}, Q_{i,t}, K_{i,t}\rangle_{i=1}^{Nt}$, the quantity of T-bonds offered for sale O_t , the reservation price of the seller R_t, the maximum quantities each bidder can buy in the auction $\langle \bar{Q}_{i,t}\rangle_{i=1}^{Nt}$; i.e. $\tilde{q}_{i,t} = \tilde{q}_i\left(\langle b_{i,t}, Q_{i,t}, K_{i,t}\rangle_{i=1}^{Nt}, R_t, \langle \bar{Q}_{i,t}\rangle_{i=1}^{Nt}, O_t\right)$.

The *ex post* payoff to bidder i depends on the quatity of T-bonds she wins $\tilde{q}_{i,t}$, her type $\varphi_{i,t}$, the price paid for buying $\tilde{q}_{i,t}$ T-bonds.

$$\Pi\left(\varphi_{i,t}, \langle b_{i,t}, Q_{i,t}, K_{i,t}\rangle_{i=1}^{Nt}, R_t, \langle \bar{Q}_{i,t}\rangle_{i=1}^{Nt}, O_t\right) = \tag{3}$$

$$\int_0^{\tilde{q}_{i,t}} v_i(p, \varphi_{i,t})\, dp \tag{4}$$

$$-\sum_{k=1}^{K_{i,t}} I\left(\tilde{q}_{i,t} \geq q_{i,k,t}\right) \cdot Q_{i,k,t} \cdot b_{i,k,t} \tag{5}$$

$$-\sum_{k=1}^{K_{i,t}} I\left(q_{i,k-1,t} \geq \tilde{q}_{i,t} > q_{i,k,t}\right)\left(\tilde{q}_{i,t} - q_{i,k-1,t}\right) b_{i,k,t} \tag{6}$$

The first term (4) in equation (3) is the total value of T-bonds bidder i wins, the second term (5) is what she pays for quantities on which she is not rationed, and the last term (6) is what she pays on quantities on which she is rationed.

Pure strategy is a list of submitted bids based on the observed information that bidder i knows before the auction, including her type $\varphi_{i,t}$, the reservation price, the distribution of all bidder values, the quantity of T-bonds for sale, and the number of opponents, ??? macro variables, micro variables, expectation about future. For the sake of simplicity I will write the pure strategy as a function of private values only. Bidder i's pure strategy is a measurable mapping from the set of private signals to the set of weakly decreasing step functions with less than K_i steps $\beta_i : \Phi_i \, S_i$.

We will assume that bidders use pure symmetric strategies within each bidder's category c.

We assume that supply is non-random, although the MFČR reserves the right to withdraw supply entirely. This happens rarely (once in the history of Czech treasury auctions, when the yield resulting from the auction exceeded that of Belgian yields (Belgium had historically higher yields because of a debt ratio more than double that of Czech Republic). Moreover MFČR reserves the right to sell more T-bonds then O_t that is announced before the auction. I will assume that bidders are ignoring these changes in supply.

When the opponents use strategies $\beta_{-i}(\cdot)$, then the *ex ante* pointwise payoff to the bidder, whose type is $\varphi_{i,t}$ and who bids $\langle b_{i,t}, Q_{i,t}, K_{i,t}\rangle$ is:

[3] The total submitted cumulative quantity is at most $\bar{Q}_{i,t}$. The seller truncates the demand curve; i.e. $y_{i,t}(p|\varphi_{i,t}) = 0$ if $q_{i,K_{i,t}} > \bar{Q}_{i,t}$

$$\prod\left(\varphi_{i,t}, b_{i,t}, Q_{i,t}, K_{i,t} \mid R_t, \beta_{-i}(\cdot), O_t\right) = \int_0^{\tilde{q}_{i,t}} v_i\left(p, \varphi_{i,t}\right) dp \tag{7}$$

$$-E\left(\sum_{k=1}^{K_{i,t}} I\left(\tilde{q}_{i,t} \geq q_{i,k,t}\right) \cdot Q_{i,k,t} \cdot b_{i,k,t}\right) \tag{8}$$

$$-E\left(\sum_{k=1}^{K_{i,t}} I\left(q_{i,k-1,t} \geq \tilde{q}_{i,t} > q_{i,k,t}\right)\left(\tilde{q}_{i,t} - q_{i,k-1,t}\right) b_{i,k,t}\right) \tag{9}$$

The expectations in terms (8) and (9) are taken over possible opponent types $\langle\varphi_{j,t}\rangle_{i\neq j}$ which induces the probability measure of the E operator.[4] I use the word payoff to mean the *ex ante* payoff when no confusion arises.

The bidder maximizes his payoff from a strategy $\beta_i(\cdot)$:

$$\max_{\beta_i(\cdot)} E\left(\prod\left(\varphi_{i,t}, b_{i,t}, Q_{i,t}, K_{i,t} \mid R_t, \beta_{-i}(\cdot), O_t\right)\right) \tag{10}$$

The expectations in terms (10) are taken over all possible types $\varphi_{i,t}$ of bidder i which induces the probability measure of the E operator.

The equilibrium concept we use is Bayesian Nash equilibrium. A vector of strategies y(·|)) constitutes a Bayesian Nash equilibrium if for all bidders i, yi(·| i) maximizes her expected utility i(i).

Similarly to Kastl (2012) we derive the first-order condition.

Let $\mathrm{P}^{S}(\varphi, \mathrm{y}(\cdot \mid \varphi))$ denote the stop-out price associated with type vector φ. Kastl (2012) shows that for all steps k but the last step K_i a bidder's bid function has to satisfy

$$\mathrm{v}\left(\mathrm{q}_k, \varphi_{i,t}\right) = \mathrm{b}_{i,k,t} + \frac{\Pr\left(\mathrm{b}_{i,k+1,t} \geq \mathrm{P}_t^S\right) \cdot \left(b_{i,k,t} - b_{i,k+1,t}\right)}{\Pr\left(\mathrm{b}_{i,k,t} \geq \mathrm{P}_t^S > \mathrm{b}_{i,k+1,t}\right)} \tag{11}$$

We describe how to infer the marginal valuations of bidders from the above equation using resampling.

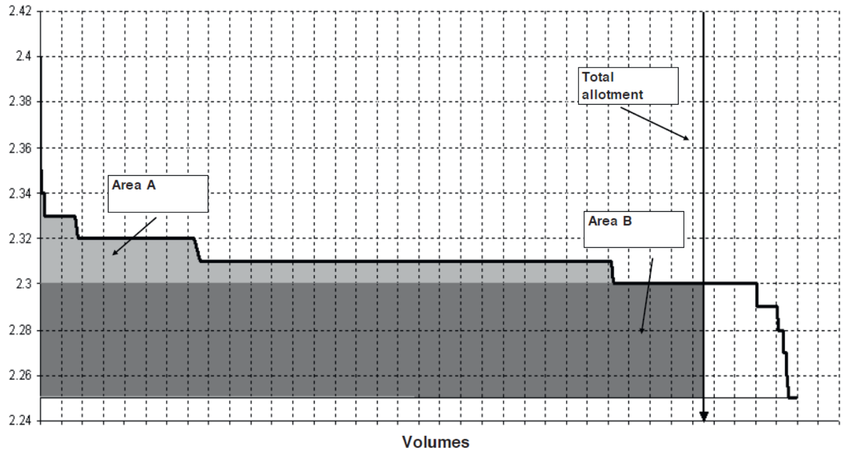
This way we will construct series of $\hat{v}_{i,k,t}$.

We define $\widehat{U}_{i,t}^3 = log\left(\left(\hat{v}_{i,j,t} - S_t\right) \cdot q_{i,j,t}\right)$ where S_t is the expected secondary market value; i.e. $\frac{{b_{i,t}}^a - {b_{i,t}}^b}{2}$ or the sellers minimum accepted price.

[4] If the supply supply is random, then the induced probability measure takes this into account.

Annex 3: Additional Charts

Chart A3.1: A central bank auction and the funding liquidity risk measures.



Note: Thick black line is the aggregate demand curve. LRP=[(Area A + Area B)/ total allotment], LRP_1=[Area A / total allotment]

Therefore we will calculate the avarage weighted T-bond value of bidder i substracted from some benchmark. We will use a seller's reservation price or secondary market price as benchmark. There is an analogy between constructing of our average value indicator and the approach used by Drehmann and Nikolaou (2009), who construct this indicator for the euro area. The measure is analogous to market liquidity index MIBL used for a particular bidder i (see CNB (2008, p.35) for the details).

What value measure to choose?

Volume of demanded T-bonds $$\bar{b}^1_{i,t} = (b_{i,j,t} - S_t) \cdot q_{i,j,t} \tag{12}$$

Weighted average value of T-bonds $$\bar{b}^2_{i,t} = \frac{(b_{i,j,t} - S_t) \cdot q_{i,j,t}}{\sum_{k=1}^{K_i} q_{i,j,t}} \tag{13}$$

Log of (12) $$\bar{b}^3_{i,t} = log(b_{i,j,t} - S_t) \cdot q_{i,j,t} \tag{14}$$

Log of (13) $$\bar{b}^4_{i,t} = log\left(1/\left(\frac{(b_{i,j,t} - S_t) \cdot q_{i,j,t}}{\sum_{k=1}^{K_i} q_{i,j,t}} + \varepsilon\right)\right) \tag{15}$$

Given that all opponent bidders $-i$ submit $\langle b_{-i,t}, Q_{-i,t}, K_{-i,t}\rangle$ one can define residual supply for bidder i as as the total amount of T-bonds offered for sale minus the demand of the opponent bidders $-i$

$$RS_{i,t}(p) = O_t - \sum_{j \neq i} y_{j,t}(p|\varphi_{j,t}) \tag{16}$$

To infer the valuations at the bid steps, we follow the resampling approach proposed by Hortacsu and McAdam (2010) and Kastl (2011).

To infer the valuations at the bid steps, we follow the resampling approach proposed by Hortacsu and McAdam (2010) and Kastl (2011). The first-order condition is not tractable analytically unless a specific form of the marginal value distribution function has been specified (see Hortacsu

(2002),. Fevrier et al. (2004), Wolak (2003)). This kind of simplification may justify the usage of parametric methodologies in a few special cases. But I will focus on structural auction modeling advocated by Bajari and Hortacsu (2005) and discussed also in Athey and Haile (2009) and Henddricks and Porter (2007). Kastl (2010) applies this approach to auctions of Czech T-bills and Cassiola et al. (2010) applies this approach to ECB auctions. In their approach one constructs the residual supply curve for each bidder. This curve can be derived from the total number of T-bond offered for sale in the auction by the seller and the bids submitted by the opponent bidders. After that they use various analytical tools for estimation of the demand and supply equations. Their methodology also accounts for asymmetric behavior in the auctions.

Since bidders are assumed to have private values, each bidder i cares about others' bidding strategies only insofar as they affect the distribution of bidder i's residual supply. Our approach to estimate this distribution is based on resampling from the observed set of bids. The theoretical background for resampling is derived above in the equation (11) derived above

$$v(q_k, \varphi_{i,t}) = b_{i,k,t} + \frac{\Pr(b_{i,k+1,t} \geq P_t^S) \cdot (b_{i,k,t} - b_{i,k+1,t})}{\Pr(b_{i,k,t} \geq P_t^S > b_{i,k+1,t})}$$

Consider for the moment the special case in which all T auctions in the sample have identical covariates. The following "resampling" procedure greatly simplifies the estimation problem.

1. Fix bidder *i* from group A and his K bids $b_{i,K}$ made by this bidder. Let me denote NA number of bidders in group A and NB number of bidders in group B.
2. Draw a random subsample of $N_A - 1$ bid vectors with replacement from the sample of N_A bids in the data set and N_B bid vectors from the sample of N_B bids in the data set.
3. Construct bidder i's realized residual supply according to equation (16) above where the opponents submit these $N_A - 1$ and N_B bids, to determine the realized market-clearing price given i's bid $b_i(.)$, as well as whether bidder i would have won quantity qi at price b_i for all (q_i, b_i).
4. This allows one to consistently estimate each of bidder i's winning probabilities Pr($b_{i,t}$ $>P_t^S>b_{i,k+1,t}$) and Pr($b_{i,k,t}$ $>P_t^S>b_{i,k+1,t}$), simply as the fraction of all subsamples given which bidder i would have won a k-th unit at price p.
5. Repeating this process many times allows to estimate expected value E(v($q_{k,t,}\varphi_{i,t}$)) using equation (11).

Then I will explain these revealed marginal valuations $v_i\left(q \mid I, II_i\right)$ from the information sets I, II_i available to the bank at the time of auctions. We will regress marginal values v_i for a given quantity observed in submitted bids on the explanatory variables I, II_i.

$$v_i = \alpha_0 + II_i\,\alpha_1 + I\,\alpha_2 + \varepsilon_i$$

I will also consider spreads between marginal values and interbank interest rate variables. Then in the parameters α_1, α_2 will allow us to test various hypothesis on the relations between the interest rates.

I will address the following hypotheses:

- We will investigate the effect of the volume of maturing T-bonds around the auction day on the dealers' demand in auctions. Does the number of tranches influence behaviour of dealers in auctions?
- Are the bidding strategies affected by adjusting total auction volume after bid submission?
- What is the effect of T-bond sale on the dealers' portfolio? How does the dealer's portfolio change~~s~~? Does this change depend on their CDS? How does the bidding function depend on CDS of primary dealer's and clients CDS? What factors affect the fraction of the debt financed by domestic financial institutions and what fraction is financed by the rest of the world?
- Is the demand in T-bond auctions higher in the case of participants which resale the T-bonds more around the auction day?
- What measures can enhance the performance of the primary auction market of T-bonds?
- How the bidding behavior of banks in T-bond auctions changed during the recent economic and financial crisis? In particular, CDS of individual banks increased in September 2008, increasing the demand for collateralised transactions. This may have increased the demand for T-bonds and thus their price. On the other hand, the fears from future additional negative liquidity shocks decreased the demand for collateralised transactions and thus the demand for T-bonds declined. We will test which of the two effects prevailed.
- How the introduction of CNB liquidity providing REPO operations in October 2008 affected the bidding behavior of banks in T-bond auctions? We will test whether the effect on the demand for T-bonds was positive.
- We will investigate contagion effects from abroad on the behavior of dealers. In particular, CDS of a number of EU countries increased significantly in March to May 2009 (CEE countries) and also in March to May 2010 (Greece).
- What publicly available information has significant effect on bidder strategies?

Some preliminary empirical findings will be discussed during the presentation.

CONCLUSION

In this paper, I design and analyze a model of a uniform price and discriminatory price auctions. The seller offers several identical units for sale to n bidders. The seller is flexible in adjusting the number of supplied units ex-post that simplifies the analyzis. The theory suggests that bidder behavior mimics the best response behavior of an oligopolist who faces fixed total demand. In such an oligopolistic game each agent does not know the private information of the competitors and therefore faces uncertain demand. In this model one can design appropriate estimation techniques and hypothesis testing to analyze multi-unit auction data. The estimation method enhances to capture heterogeneous impact of global financial crises on individual banks from disaggregated level data perspective. Although Czech banking system was not directly hit by sub-prime crises because the exposure to toxic assets was not significant, the liquidity hoarding and interest rate spread widening is present in the Czech Republic similarly to markets in the US, UK and Euro Area, albeit to a much lesser extent. Through the model of bidding we will argue that the bank value for liquidity has been much more dispersed than the raw bidding data show.

APPENDIX: Bootstrap in STATA to estimate values.

```
clear
set more off

cap log using P, text replace

scalar drop _all

*cd c:\Work\Projekty\Dluhopisy_D211
*nacti data2.xlsx
import excel using data2.xlsx, firstrow

*seznam dealeru
egen dealer=group(primary_dealer)

*priprava dat
gen tender2=lower(trim(itrim(tender)))
gen security2=lower(trim(itrim(security)))
gen tender_number2=lower(trim(itrim(tender_number)))
gen settlement_date2=lower(trim(itrim(settlement_date)))
* tohle musime opravit, je to tendr c.64
*list if tender2=="gb 2.90/08, 6.95/16 comp"
*list tender2 security2 tender_number if tender2=="gb 2.90/08, 6.95/16 comp"
replace tender2="gb 6.95/16 comp" if tender_number2=="64"
replace tender2="gb 2.90/08 comp" if tender_number2=="64_2.90"
*list tender2 security2 tender_number if tender_number2=="64" | tender_number2=="64_2.90"
*list  tender2 security2 settlement_date2 tender_number2 in 1/20
* precislujeme cisla tendru, protoze mame dvakrat 64
* mensi nez 64 budou o jednicku mensi, "64_2.90" bude mit cislo 64 a dale to bude stejne jako tender_number2
gen tn3=tender_number2
replace tn3="" if tender_number2=="64_2.90"
destring tn3, replace
replace tn3=tn3-1 if tn3<=64
replace tn3=64 if tn==.


*39:
keep if comp=="C"

*oznacime cisla aukci
egen tenderindex=group(tn3)
sort tenderindex
*pocet comp. tenderu
scalar totalcomptenders=tenderindex[_N]
scalar list
```

```
*45 petkrat MC
*pro kazdou aukci:
local i=1
*while `i'<=totalcomptenders {
while `i'<=2 {
	*zjisti pocet ucastniku v aukci, oznac je (cislama)
	egen bidderindex`i'=group(dealer) if tenderindex==`i'
	*51:pocet dealeru v aukci
	egen numberofd`i'=max(bidderindex`i') if tenderindex==`i'
	egen nd`i'=max(numberofd`i')
	scalar numberofdealers`i'=nd`i'[1]
	drop nd`i'
	scalar list

	*do matice (souboru) A budeme po radcich ukladat vysledky:
	*kazdy radek je nahodny vyber oponentu, pocet sloupcu je numberofdealers-1; pocet radku je numberofdealers (tj. pro kazdeho biddera delam nahodny vyber z oponentu)
	*na konec pridam posledni sloupec s bidderem

	*53: for bidderindex=1 to pocetucastnikuvaukci (cyklus pro kazdeho dealera v aukci)
	local j=1
	while `j'<=numberofdealers`i' {

		local k=numberofdealers`i'-1
		*pro kontrolu:
		scalar kk=`k'
		scalar list

		*54: oponenti (seznam)
		*55: pocet oponentu (=numberofdealers-1)
		*56: matice nahodnych cisel s opakovanim, oponenti
		preserve
		bsample `k' if tenderindex==`i' & bidderindex`i'!=`j'
		keep bidderindex`i'
		*sloupec transponujeme na radek
		xpose, clear
		*ulozime jeden novy radek, kde pocet sloupcu je numberofdealers-1
		save r`j', replace
		restore
		local j=`j'+1
		}

	*z radku vytvorime soubor (matici), ktery ulozime jako A`i'
	preserve
	use r1, clear
	local m=2
	while `m'<=numberofdealers`i' {
		append using r`m'
		erase r`m'.dta
		local m=`m'+1
		}
```

*musime do matice pridat posledni sloupec s vlastnim bidderem (ktery nebyl oponent), dame tomu cislo treba 20

```
	gen v20=_n
	save A`i', replace
	erase r1.dta
	restore

	local i=`i'+1
	}
```

*promenne s poradovymi cisly `i' (kde mimo danou aukci je to missing) nahradime promennymi bez cisel

```
	egen bidderindex=rowmax(bidderindex*)
	egen numberofdealers=rowmax(numberofd*)

	*puvodni promenne s poradovymi cisly vymazeme
	local i=1
	*while `i'<=totalcomptenders {
	while `i'<=2 {
		drop bidderindex`i' numberofd`i'
		local i=`i'+1
		}

*seradime a ukazeme si, jak to vypada:
sort tenderindex bidderindex
list tenderindex bidderindex numberofdealers price2 yield2 original_bid if _n<110, sep(200)
```

*ZDE KONEC

/*

(nejaky tisk)

64: for poradovecislonahodnehovyberu=1 to pocetMC (tj. pro kazdy bsample)

67-68: matice A - do nahodneho vyberu oponentu pridam biddera
69-73: prida do matice A jako dalsi radky bidy oponentu
tj. matice A je fiktivni aukce (oponentni jsou bsample)

usporadej matici A podle price (sestupne)
vysledek uloz do matice A1 (r.79)

80: zjisti pocet radku matice A1 (pocet objednavek)
82: do sloupce 100 v matici A1 budu davat kumulativni demand fiktivni aukce

83: for radky matice A1 od radku 2
spocita kumulativnidemand

86: jestli kumulativni demand prekrocila nabizene mnozstvi v aukci (total_amount_allocated)
87 aj. podminka, kdyz jich je vice (kde se to deli) - nas nezajima, protoze ukladame jen vyslednou cenu, ktera je u nich stejna

88: do promenne Pc se ulozi vysledna fiktivni cena aukce

106: vzorec, AT paper maji chybu, spravne je Kastl(2012)

zaver: vedle sloupecku price budu mit sloupec value (spocitany podle vzorce) */

set more on
log close

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