The 2007 Subprime Market Crisis Through the Lens of European Central Bank Auctions for Short-Term Funds

Nuno Cassola, Ali Hortaçsu and Jakub Kastl

June 24, 2009
Road plan

1. Background info: EURO money markets.
2. Model of bidding
3. Evidence of liquidity crisis from the bidding behavior in the primary market
4. Quantification of this effect using a model of bidding
5. Implications of our findings for informational content of various interest rates
6. Examine bidder heterogeneity
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EURO money markets

MRO - main refinancing ops (1 wk; every week)
Standing facility -- overnight loans/deposits (MBR +/- 100 b.p)
LTRO - long-term refinancing ops (3 mo; every month)
FTO - fine-tuning ops (no fixed maturity; every month)
Interest Rates Evolution

![Graph showing the evolution of interest rates over time with various rates such as 1-w swap rate (EONIA), 1-w repo rate (EUREPO), and 1-w unsecured rate (EURIBOR).]
Key Interest rates:

- **EURIBOR**: unsecured loans, average of rates submitted by panel banks: “daily quotes of the rate that each panel bank believes one prime bank is quoting to another prime bank for interbank term deposits within the Euro zone”

- **EUREPO**: collaterized loans, average of rates submitted by panel banks: “Panel Banks are submitting the best bids in the market. However, Panel banks submitting the bids are expected, under normal circumstances, to transact at these levels.”

- **EONIA swap rate**: “the average rate at which a representative panel of prime banks provide daily quotes that each Panel Bank believes is the Mid Market rate of EONIA swap quotations between prime banks”
  - An “EONIA swap” is an interest rate swap transaction, where one party agrees to receive/pay a fixed rate to another party, against paying/receiving a floating rate named EONIA (which is average of all actual overnight unsecured transactions).
2007 Subprime Crisis:

- August 9th, 2007: BNP Paribas announces the freeze of 3 huge investment funds
- In the 2nd half of 2007: volume in term interbank markets diminishes: liquidity shifts to less than 1-week maturities in secured (repo) transactions, and to overnight lending in unsecured.
- There is significant shift from bilateral and electronic transactions back to “voice-brokers” and electronic markets that serve as centralized clearing houses (anonymity?)
“Risk” Evolution (if rates comparable pre- and after)

Difference between 1–w unsecured rate (EURIBOR) and 1–w repo rate (EUREPO)

August 9, 2007 (week 32)
(Normalized) Bidding in Primary Market

Bidding Behavior in auctions

Bid – EONIA (Before: −, After: −.)
This paper:

- The turmoil marked a drastic change in bidding behavior in the primary market
- Since virtually all bidders started bidding more aggressively, was there a significant change in the fundamentals? (such as increase in their underlying marginal values)
- Can we use the data to tell which bidders are likely hit substantially by the crisis?
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This paper: preview of results

- we estimate a structural model of bidding in these auctions using data from the ECB
- the estimated values for liquidity obtained in the primary market allow us to:
  1. decompose the “equilibrium adjustment” and “shift in primitives” effects (based on bidding, about 90% of bidders react to the turmoil by substantially increasing their bids)
  2. talk about implied bidder-specific collateral structure and secondary market rates that would rationalize the bidding behavior in the primary auctions
- we argue and document that for about $\frac{2}{3}$ of these bidders, the turmoil was accompanied with a significant shift (in terms of first order stochastic dominance) in their distribution of marginal values for liquidity in the primary market, while $\frac{1}{3}$ simply adjusted their best-reponses
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Related Literature

Model: Demand for ECB liquidity

- Bank $i$ needs $R_i$ units of liquidity
- Has $L_i$ units of “liquid” collateral: Euro gov’t bonds, can borrow at secured rate $s_i$ against these
- Has $K_i - L_i$ units of “illiquid” collateral: e.g. asset-backed securities (ABS), retail mortgage backed securities (RMBS)
- Marg. cost of borrowing $q$ units against illiquid collateral $s_i + c_i(q)$.
- Funding needs beyond $K_i$ can be satisfied at interbank unsecured rate $u_i$. 
Demand for ECB Liquidity, $v_i(q)$

Marginal Valuation of a Bidder

- **Unsecured rate**
- **Secured rate**
- **Marg. valuation**

$Y = R - K$
$Y = R - L$
Bidding in a Pay-as-Bid Auction

- based on Wilson (1979)
- Private information: $s_i \sim F(s)$. $s_i$ can consist of $\{R_i, K_i, L_i, s_i, u_i, c_i(.)\}$.
- Marginal valuation function: $v(q, s_i)$
- Pay-as-bid Auction: Bidders pay their bid for every unit they win
- bids consist of finite number (10) of steps (price-quantity pairs)
- Supply is uncertain, pro-rata rationing on the margin
Motivation | Model | Data | Results | Conclusion
---|---|---|---|---

Model: Divisible Good Auction

- A1: (Independence) *Conditional on observables* prior to auction, $s_i$ is independent across bidders
- A1': $s_i$ are iid within (small number of) classes of bidders
- A2: (Private values) Learning $s_i$ does not affect $v(q, s_i)$.
- Equilibrium: Bayesian Nash
- Euler equation:
  $$\nu(q_k, s_i) = b_k + \frac{\Pr(b_{k+1} \geq p^c)}{\Pr(b_k > p^c > b_{k+1})} (b_k - b_{k+1})$$
- Uncertainty about market clearing price creates a wedge between marg valuation and bid!
What do we learn from $v_i(q)$?

First step of $v_i(q)$: $u_i$, unsecured rate faced by bidder $i$

Last step: upper bound on $s_i$, unsecured rate faced bidder $i$

Maximal demand: $R_i - L_i$ (or $R_i$)

Downward sloping part of $v_i(q)$: market discount on illiquid collateral.
Recall:

\[ v(q_k, s_i) = b_k + \frac{\Pr(b_{k+1} \geq p^c)}{\Pr(b_k > p^c > b_{k+1})} (b_k - b_{k+1}) \]

Therefore we need the distribution of the market clearing price.

Obtain this distribution by simulation: drawing with replacement \((N-1)\) bids from the observed bids, subtract from the supply and intersect thus obtained residual supply with a bidder’s bid to obtain one possible market clearing price.

Many such simulation draws will result in a distribution of the market clearing price.

Note that this distribution depends on a bidder’s bid (hence it is bidder specific!)
Estimation in the symmetric iid case

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Resampling method

Resampling procedure for bidder 1

Actual bid function
Residual supply functions

Histogram of p for bidder 1
Is the symmetry assumption appropriate?

In particular, we hypothesize that a subset of banks is hit by the crisis more than the others.

We implement an iterative procedure:

1. Estimate the model assuming symmetry
2. Estimate which banks are in trouble based on the analysis of the estimated values from step (1)
3. Estimate the model assuming two asymmetric groups within which bidders are symmetric where the split is determined in step (2).
4. Repeat step (2) until convergence.

Caveat: we do not have a general proof of convergence.
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50 auctions of 1-week loans run by the ECB
- discriminatory auction format
- ECB requires bidders to post collateral (next slide) with their respective central banks against the loans (otherwise penalties enforced). Eligible collateral broader than interbank repo transactions.

Sources of heterogeneity, (conditional) private values:
- Reserve requirements, $R_i$
- Interbank funding opportunities: $s_i$, $u_i$
- Collateral positions: $K_i$, $L_i$
High quality collateral becomes costly! It moved out from primary market to interbank market. Collateral management becomes very important!
## Data

### Summary Statistics

<table>
<thead>
<tr>
<th>Summary Statistics</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auctions</strong></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>341</td>
</tr>
<tr>
<td>St.Dev.</td>
<td>28</td>
</tr>
<tr>
<td>Min</td>
<td>273</td>
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<tr>
<td>Max</td>
<td>395</td>
</tr>
<tr>
<td><strong>Bidders (cca 700 identities)</strong></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>3.94</td>
</tr>
<tr>
<td>St.Dev.</td>
<td>0.22</td>
</tr>
<tr>
<td>Min</td>
<td>3.50</td>
</tr>
<tr>
<td>Max</td>
<td>4.36</td>
</tr>
<tr>
<td><strong>Submitted steps</strong></td>
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</tr>
<tr>
<td>Mean</td>
<td>1.66</td>
</tr>
<tr>
<td>St.Dev.</td>
<td>1.02</td>
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<td>Min</td>
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<tr>
<td>Max</td>
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<tr>
<td><strong>Price bid</strong></td>
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<tr>
<td><strong>Quantity bid (per cent of supply)</strong></td>
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<tr>
<td>Mean</td>
<td>0.004</td>
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<tr>
<td>St.Dev.</td>
<td>0.012</td>
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<td>Min</td>
<td>$3 \times 10^{-6}$</td>
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<td><strong>Issued Amount (billions Euros)</strong></td>
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<td>Mean</td>
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<tr>
<td>St.Dev.</td>
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<tr>
<td>Min</td>
<td>155</td>
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<tr>
<td>Max</td>
<td>330.5</td>
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## Data: Before and After Turmoil Start

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we estimate marginal values for each bidder

Compare marginal values for liquidity in the primary market to the repo-rate in the secondary market (EUREPO) and to the unsecured rate (EURIBOR).
Results: Aggregate value before turmoil

Bidding Behavior in auction32

- Marg val
- Bid
- EONIA
- RepoRate
- Euribor

Quantity Share demanded vs. Yield

0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0

Yield: 4.04, 4.05, 4.06, 4.07, 4.08, 4.09, 4.10, 4.11, 4.12

Quantity Share demanded: 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0
Results: Aggregate value before turmoil

- Values bounded for most part from above by the unsecured rate (the riskiest one) EURIBOR and from below by the "risk-free" rate - fully collateralized rate EUREPO (highest quality collateral used)
- "First step" of marg val schedules: clustered around EURIBOR, i.e. $u_i$ are close to EURIBOR before the turmoil
- Market cleared at the repo-rate. Some bidders gain infra-marginal surplus by utilizing (relatively) illiquid collateral to borrow at secured rate from ECB, but there's rationing.
Results: Aggregate value in Sep 2007

Bidding Behavior in auction34

- Marg val
- Bid
- EONIA
- RepoRate
- Euribor

Yield vs. Quantity Share demanded graph.
Results: Aggregate value in Sep 2007

- Values bounded again (for the most part) from above by the unsecured rate (the riskiest one) EURIBOR and from below by the “risk-free” rate - EUREPO
- Note: market cleared significantly above the repo-rate!
  Marginal discount for illiquid collateral is 9 basis points (as opposed to 1.5 b.p. in previous slide)
- In fact there are auctions, in which the market cleared ABOVE the unsecured rate!
Results: Aggregate value after turmoil

Bidding behavior (−) and marginal values (x) in auctions after turmoil (auction 45)
Results: Aggregate value in Nov 2007

- Most bidders cannot borrow at EURIBOR. Unsecured rates faced by bidders 5-8 b.p. above EURIBOR. Some much higher!
Interest rates and market clearing

Interest rates

- 1-w repo rate (EUREPO)
- 1-w unsecured rate (EURIBOR)
- Clearing rate
- Turmoil

Auction Yield

0 5 10 15 20 25 30 35 40 45 50

Motivation Model Data

Results

Conclusion
Results: Clearing above unsecured rate

Why are there auctions in which the market cleared above the unsecured rate?

EURIBOR is constructed from a survey of member banks about “beliefs of offer rates”

In particular, banks perceived as risky by other lenders would probably not be getting a loan in the unsecured market or would get it at worse terms
Results: Clearing above unsecured rate

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Results: Evolution of aggregate marginal value

Figure: Quantity-weighted average marginal values (across all bidders)
(Normalized) Marginal Values in Primary Market

Marginal values in auctions

- Marg val – EONIA (Before: −, After: −.)
Results: Evolution of aggregate marginal value

- Possible explanations:
  1. Marginal values increased quite a bit at least for a subset of bidders
  2. EONIA swap rate is a wrong interest rate to normalize with after turmoil
Results: Effect on marginal values of individual bidders

- Which bidders are affected the most?
- Regress quantity-weighted marginal value for each bidder on the turmoil dummy.
Histogram of Significant Turmoil Effects

- Turmoil results in increase in the marginal value of 10 basis points on average (up to 66 basis points)
Classifying troubled bidders

- Can we use our methodology to identify distressed banks?
- With current data yes. (We hope ECB will match our predictions at least after some time with the actual bank failures/troubles.)

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Notice that analysis based solely on bids (ignoring the equilibrium adjustments) would severely overestimate the number of affected banks! (88% rather than 66% based on values)
Predicting problems?

- In the future: if ECB utilized our approach “regularly”, banks would likely adjust their bidding behavior.
- A placebo test (doing the same exercise as above, but only based on 32 auctions pre-turmoi, where the artificial break is assumed at auction 16.) shows that the results are not due to “chance”.

Participation frequency of bidders with Significant Turmoil Effects

Histogram of participation frequency of bidders with significant coefficients on turmoil dummy

Risk factor: Bidders who participate more often in MROs
Participation frequency of bidders with Insignificant Turmoil Effects
Some insights from a simplified model

- If bidders are constrained to submit only one price-quantity bid:
  \[ v_i = \alpha_i s_i + (1 - \alpha_i) u_i \]

- \( \alpha_i \) is the ratio of ECB-acceptable collateral that is also acceptable in the secondary market

- BUT: bank-specific rates not observed, but it may be reasonable that \( s_i \) is fairly constant across banks (even though some bank-specific risk of the “capture” of collateral might be priced)

- Thought experiment: use the published rates \( u \) (EURIBOR), \( s \) (EUREPO) together with estimated \( v_i \) and back out the implied convex combination weights \( \alpha_i \) .
Linking values in the primary market with bank-specific interest rates in the secondary market

- Estimates: Median $\alpha$ pre-turmoil: 0.29, post-turmoil: $-0.02$!
- $\alpha_i$’s do not lie between $[0,1]$ - more than 50% of banks cannot borrow at the published EURIBOR rate!
- Decomposing this change in $\alpha_i$ into “distressed” and sound banks: change in mean from 0.18 to $-0.02$ for the first group, from 0.466 to 0.474 for the latter group.
Linking values in the primary market with bank-specific interest rates in the secondary market

- Abandon the assumption that all banks face $u$ and instead compare $v_i$ directly with $u$ and $s$.
- Per auction: even pre-turmoil about 40% of banks have estimated values above EURIBOR!
- Post turmoil this fraction increases to 58%!
- EUREPO (secured rate) indeed places a lower bound on the estimated values for vast majority of banks
Distribution of crisis across Euro-zone countries

Alpha by country (participants only)

Country: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Pre-turmoil: Blue bars
Post-turmoil: Red bars
For a subsample of banks we obtained data which is likely to be correlated with their private information, $s_i$.

- Daily observation of monthly reserve requirements (used on the day of the auction), credit default swaps (CDS), size
Private Information

- For a subsample of banks we obtained data which is likely to be correlated with their private information, $s_i$
- Daily observation of monthly reserve requirements (used on the day of the auction), credit default swaps (CDS), size
### Analysis of Marginal Values

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Analysis of Marginal Values

- EUREPO highly correlated with values
- deficiency has a positive impact after turmoil
- liquidity obtained in LTROs (3-m maturity loans) results in lower values for liquidity in MROs pre-turmoil, but there is funding complementarity post-turmoil
- RCDS positive after turmoil
Conclusion

- Subprime crisis had a huge impact on the primary market for liquidity!
- It was not just a shift to a different equilibrium, but the model primitives changed!
- For over $\frac{2}{3}$ of the bidders, the value for obtaining liquidity in the primary market increased substantially. (Bids significantly increase for 88% of bidders.)
- This suggests that for many banks the primary market became the only viable option for obtaining liquidity (some auctions even cleared above the unsecured rate!)
- Banks might have used the primary market more in order to improve their balance sheets
- Due to increased heterogeneity of values and the associated misallocation of liquidity (as the secondary market does not function properly to rectify it) the primary auctions play an important role to improve allocative efficiency