Empirical Analysis of Financial Markets Using Tools from Industrial Organization

Jakub Kastl

Princeton University

August 21, 2015

Talk Outline

1. Market Power, Market Structure, Front-running
   - U.S. Treasury
   - Canadian Treasury
2. Learning about Over-the-Counter Markets
   - Main Refinancing Operations of the European Central Bank
3. Systemic Risk
   - Main Refinancing Operations of the European Central Bank
4. Demand Systems for Financial Assets

U.S. Treasury Auction System

- In 2013, U.S. Treasury auctioned 7.9 trillion dollars of debt
- US Debt Instruments: daily volume over $565 billion (in 2007) (Daily volume in global equity markets was about $420)
- ODM charter: "Lowest cost of financing over time". How?
- Market organized around primary dealers: 18 in 1960, 46 by 1988 and currently 22 (Primary Dealers Act (1988))
  - PD: bank or security dealer must commit to active participation in security auctions and to make bids when the Fed conducts open market operations. PDs are required to report on their activity to the Fed.
  - Is this the right market structure? (front-running, PDs, direct and indirect bidders,...)

Sovereign Debt Auctions

- Auctions as sale mechanism
  - Discriminatory (pay-as-bid, multiple price) or Uniform Price (single price)
- Do (some) bidders possess significant market power that allows them to extract monopoly rents?
- Big question (at least in the past): Could changes in the mechanism lead to significant revenue/efficiency gains?
- How big are the rents accruing to PDs from the customer order flow?
- Prior papers studying sales mechanism:
  - Hortaçsu and McAdams (JPE, 2010), Kastl (REStud, 2011), Hortaçsu and Kastl (ECMA, 2012), Kang and Puller (JIE 2008), Chapman, McAdams and Paarsch (wp, 2006), Ausubel, Cramton, Pycia, Rostek and Weretka (REStud, 2014), Hortaçsu, Kastl and Zhang (wp, 2015), and many more!

How to use the Auction Data?

- Bidders bid for multiple units: useful to think about bidding for a share of the supply (Wilson (QJE 1979))
- Typically a data set includes T auctions, number of bidders N_t, supply Q_t and bids that are typically in the form of a list of price-quantity pairs that characterize a step function: $\{(b_{it1}, q_{it1}), ..., (b_{itK}, q_{itK})\}$
- Sometimes other covariates may be present: positions on the when-issued market, other exposures, other interest rates etc.
- Goal: Use bids and knowledge of the market rules and the associated equilibrium characterization to recover the willingness-to-pay that would rationalize these observed bids. ("Laffont program")

How to use the Auction Data?

- In any model of bidding we can think of writing:

$$BID = WTP - SHADING$$

- Shading is related to the beliefs of the bidder about rivals' actions.
- Role of theory: How to decompose bids into strategic (shading) vs. non-strategic (WTP/demand) components?

Equilibrium of Uniform Price Auction

$$\underbrace{E\left(P^c | b_k > P^c > b_{k+1}\right)}_{\text{BID BY A PRICETAKER}} = \underbrace{v(q_k)}_{\text{WTP}} - \underbrace{\frac{q_k}{\Pr\left(b_k > P^c > b_{k+1}\right)} \frac{\partial \mathbb{E}\left(P^c; b_k \geq P^c \geq b_{k+1}\right)}{\partial q_k}}_{\text{MARKET POWER (SHADING)}}$$

- This is very similar to the familiar monopoly pricing formula:
  P = MC - Q*P'(Q); with uncertain demand: $\mathbb{E}P = MC - Q * \mathbb{E}P'(Q)$
- It is simply a (single agent) necessary condition for profit maximization
- $\Rightarrow$ need to estimate the distribution of P^c!
- Applications: US, Korea, Czech Republic,...

Equilibrium of Discriminatory Auction

$$b_k = v\left(q_k\right) - \frac{\Pr\left(b_{k+1} \geq P^c\right)}{\Pr\left(b_k > P^c > b_{k+1}\right)}\left(b_k - b_{k+1}\right)$$

- This is very similar to equilibrium of a first price sealed bid auction

$$b = v - \frac{G(b)}{g(b)}$$

  where $G(b)$ is the CDF of the distribution of the highest rival bid.
- $\Rightarrow$ need to estimate the distribution of P^c!
- Applications: Canada, European Central Bank, Turkey,...

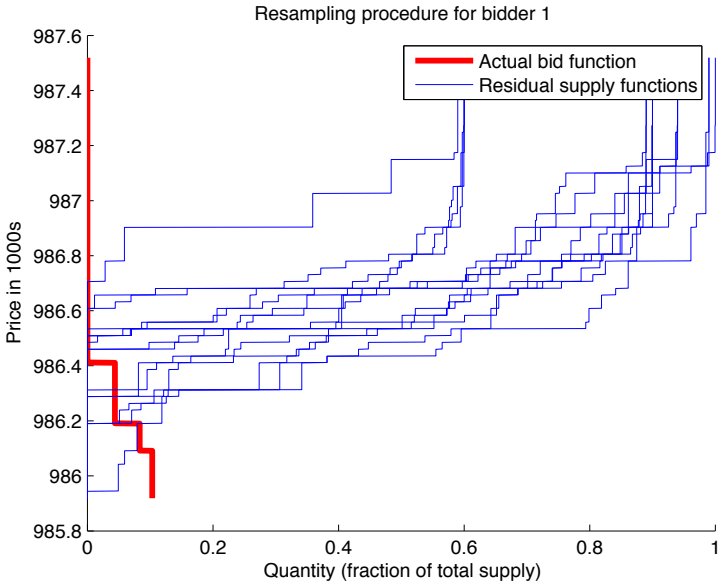
Intuition for Using Auction Data

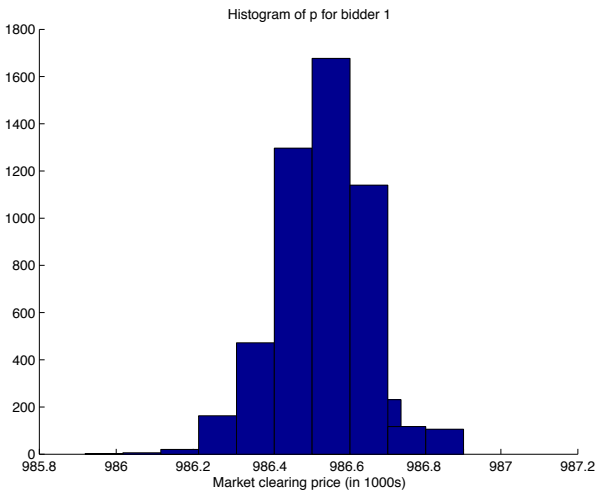
- When analyzing industries, we estimate demand using variation in supply (e.g., cost shifters).
- In an auction, the relevant (supply) curve is made up of bid schedules of other bidders, i.e. the "residual supply," which is random from perspective of each bidder.
- Hence, bidder optimizes expected profit against the *distribution* of the market clearing price (which is a function of the residual supply curves)
- Variation in observed bid curves contains information about beliefs about where the market clearing price will be.

Estimation of $F\left(P^c\right)$ in the symmetric iid case

- Hortaçsu (2002), Hortaçsu and McAdams (JPE 2010)
- We need the distribution of the market clearing price
- Obtain this distribution by simulating residual supply
  - Draw with replacement $(N-1)$ bids from the observed bids, add them up
  - 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
- This method can be generalized to asymmetries or to allow for covariates

Resampling method





Evaluating the Mechanism

- Estimate distribution of market clearing price and infer WTP using the condition for equilibrium bidding (as in Guerre, Perrigne and Vuong (2000))
- With the estimated WTP, we can calculate surplus (both ex post and expected) and efficiency.

Application 1: US Treasury Auction Data

- based on Hortaçsu, Kastl and Zhang (wp, 2015)
- Detailed bidding data from (uniform price) auctions between July 2009-Oct 2013
- Data on 3 categories of bidders:
  - Primary Dealers (purchase 63% of auction volume)
  - Direct Bidders (share rising over time (especially for notes): from less than 10% to 19%)
  - Indirect Bidders (they route bids through PDs)
- Market not very concentrated: HHI: 561 (bills), 450 (bonds) , C4: 21%, C10: 44%

How does the uniform price auction do?

- With our estimates of bidders' values, we can answer the following questions:
  1. How much money did the mechanism fail to extract (ie bidder surplus)?
     - Estimate: 2.3bp
  2. Did the mechanism implement an efficient allocation? If not, how much surplus was lost?
     - Estimate: 2.05bp
- Note: Surplus may reflect the outside option of buying bills/notes elsewhere and should not be interpreted as profits!
- Paper concludes that PDs valuations are fairly flat (and not very heterogeneous) and the auction seems competitive.
- Collusion?

Market Structure in US Treasury Auctions

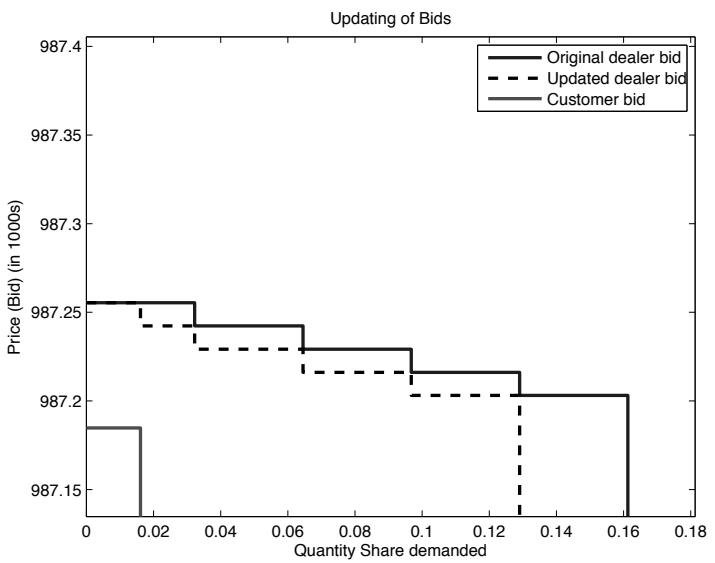
- PDs bid lower prices (higher yields) than Direct Bidders, who bid lower than Indirect Bidders
- Evaluating the shading factor from the equilibrium condition: Large bidders (PDs) have some ability to shade bids
- PDs indeed shade their bids more, but not by much! (wtp-b is larger)
- Yet PDs bid lower prices! (b's are lower)
- Adding the two effects, their implied WTP actually is higher by about 0.5bp for bills and 1-6bp for notes.

Application 2: Valuing Customer Order Flow

- Do PDs "front-run" their customers? How big are the rents from observing the order flow?
- Ideally: Observe a PD's bid, have this PD observe another bidder's (customer's) bid, and have this PD update the original bid.
- Unfortunately US Data does not have timestamps and we do not observe bid updating.

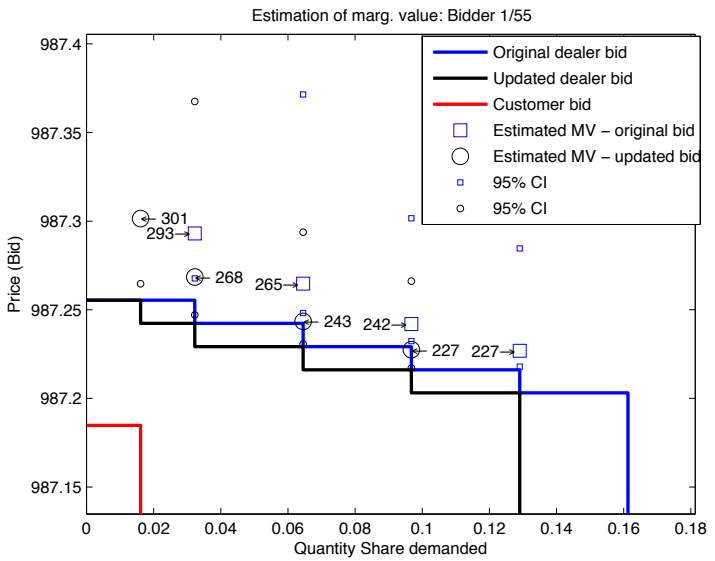
Application 2: Valuing Customer Order Flow

- Canadian Treasury Auctions (Discriminatory): Observe Bid Updating by PDs prior to the auction deadline (Hortaçsu and Kastl, ECMA 2012)
- Do PDs only learn about the degree of competition from customers' orders or do they learn about fundamentals?



Testing the Information Structure

- Learning about competition can be taken into account when simulating $F\left(P^c\right)$.
- Under the null hypothesis of "no learning about fundamentals" (ie private values between PDs and their customers), we should have $\hat{v}^{BI}(q) = \hat{v}^{AI}(q)\ \forall q$. In particular, for bids for same quantities submitted before and after the information (customer bid) arrived (most arrive in last 15 min).



Testing the Information Structure

- Result: We fail to reject that the PDs do not learn about fundamentals from customers' bids.
- Is private value assumption for treasury bills reasonable?
  - Recall that interdependent (or commmon) value environment is one in which participants have private information about some characteristics that impact the willingness-to-pay of others (and which are only imperfectly observed by others)
  - There is very active and liquid when-issued (forward) market.
  - There are other securities that are simultaneously traded with same or very similar maturity (e.g., 3m tbill with 1m left).
  - Can whatever is not captured in these markets be of first order?

Value of Customer Order Flow

- Given our estimates, we can calculate the difference in expected utility due to information arrival.
- Result: The market for Canadian treasury bills seems fairly competitive: (mean of expected surplus is $\approx$ 1.5 bp in 3-m and 0.7 bp in 12-month).
- The customer order flow leads to an increase in EU of a PD by about 27% in 3-m and about 13% in 12-m auctions.

Further Questions about Market Structure

- Why do PDs become PDs when the rents here are so modest?
  - Conjecture: they need to provide easy access to these securities in order to make their profits on complementary goods and services (advising, IPO, bond issuance).

Further Questions about Market Structure

- Did the (increasing) participation of direct bidders affect the surplus of primary dealers?
  - Conjecture: Sure! I suspect the US Treasury auctions were less competitive in the 90s.

Further Questions about Market Structure

- Do the customers voluntarily accept the rents accruing to PDs from their order flow or do they employ some sophisticated "decoy" techniques (trade splitting, timing etc.)?
- Is mechanism design first order here? (auction type, reserve price) Or are institutional details perhaps more important? (ex post supply adjustment, market structure)

Why do large players bid through PDs?

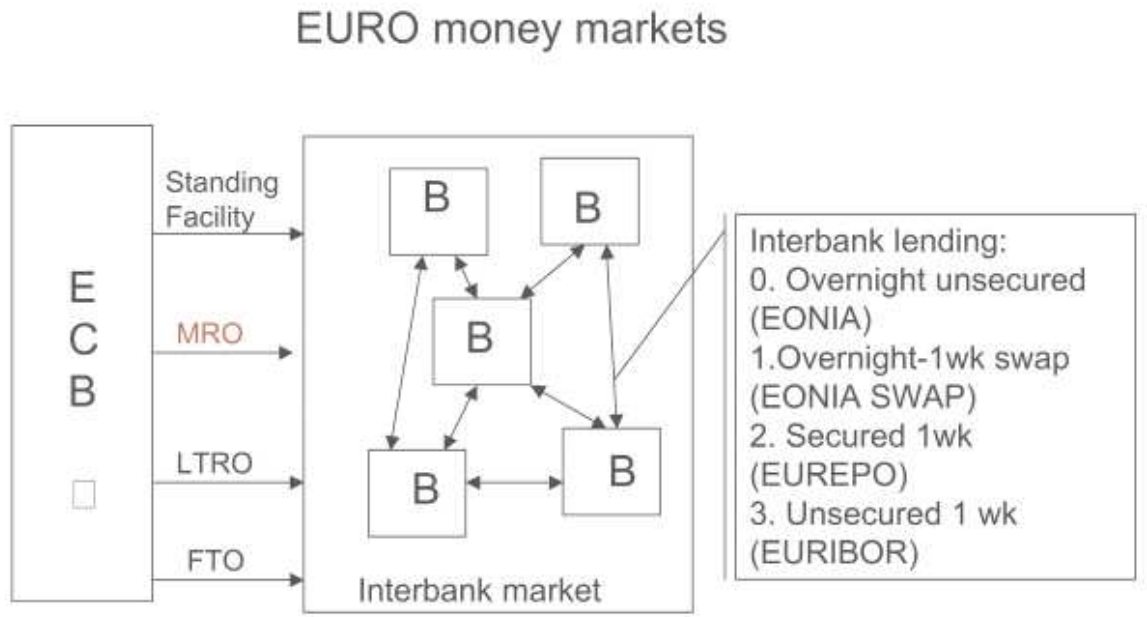
- (Bloomberg 4/4/2013) BlackRock (unlike PIMCO) doesn't bid directly because it wants to reward primary dealers for their research and other trading help.
- "While we can go direct, most of the time we dont. We feel that the dealers provide us with a lot of services. Our philosophy at this point is, to the extent we can share some of that information with trusted partners who won't misuse that information, we prefer to reward the primary dealers that provide us all that value."

Application 3: Learning about OTC Markets and Banks' "Health"

- based on Cassola, Hortaçsu and Kastl (ECMA, 2013)
- Data: Main Refinancing Operations of the European Central Bank 2007-08.
  - 1-week repo loans, allocated via a discriminatory auction (until 10/2008)
  - collateralized by securities of various quality: ranging from German tbills to various South-European mortgage backed securities
- How the 2007 crisis shows up in the banks' bidding behavior

1. . . . how to use this to identify "distressed" banks
2. . . . how to use this to peek into the OTC interbank lending markets

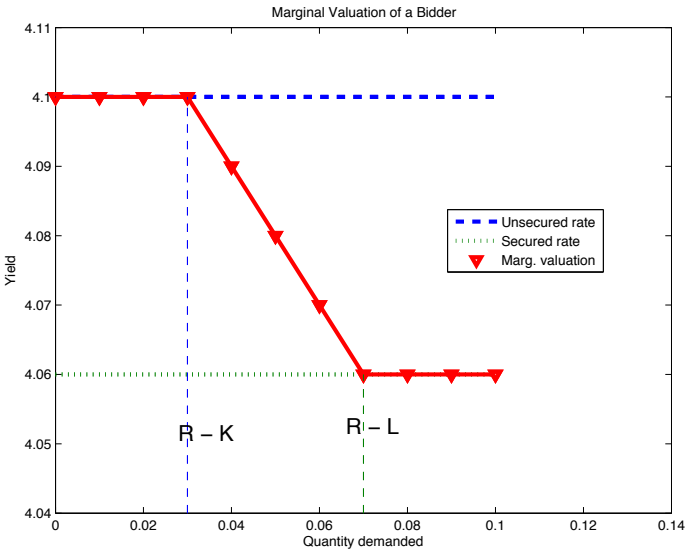
EURO Money Markets



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)

- Key idea: WTP in the auction is linked to bank's options in the interbank market and is thus informative of "funding costs" of each bank in a given week

Demand for ECB Liquidity, $v_i(q)$



- For a given liquidity need R, the shape of the WTP curve and location of steps contain information about the balance sheet of each bank (how many German tbills (most liquid, risk free, L), least liquid, where the alternative is unsecured loan, $R - K$ etc.).
- The WTP curve is approximately equal to the opportunity cost of securing the funding in the interbank market.

Distressed banks

- Introduce a latent type: "healthy" and "distressed"
- Define a bank as "distressed" if the distribution of its funding costs during the late 2007 first-order stochastically dominates its "regular" funding costs distribution estimated using early 2007.
- Implement an estimation algorithm:
  1. initial guess of the distressed banks
  2. estimate an asymmetric model given the guess
  3. classify banks based on the test for first order stochastic dominance
  4. repeat until the initial guess and final classification are within a tolerance band

Decomposing the Bids into WTP and the Strategic Effect: Is it necessary?

- Turmoil results in increase in the funding costs of 10 basis points on average (up to 66 basis points)
- About 2/3 of banks look distressed. (Based on bids alone, it would be 88%)
- Simple regressions of accounting performance measures on changes in average bids and average funding costs reveal that accounting for the strategic effect is important:

	ROE'07		
Δ bids	-0.00613		0.0734
	(0.0288)		(0.0302)
Δ marginal values		-0.0514**	-0.0553**
		(0.0230)	(0.0242)
ROE'06	0.240***	0.241***	0.242***
	(0.0299)	(0.0297)	(0.0298)

Application 4: Using Spillovers of Funding Costs to Quantify Systemic Risk

- Based on Bonaldi, Hortaçsu and Kastl (wp 2015)
- Suppose the output from previous application (a panel of funding costs of European banks) is our data
- How to estimate the network of exposures (financial network)?
- This network may arise for various reasons, e.g., due to equity holdings (Elliot, Golub and Jackson, AER 2014) or due to debt (Acemoglu et al, AER 2014)
- Define "systemic risk" as the total effect of a shock to a bank's funding costs on the other banks.

Using Spillovers of Funding Costs to Quantify Systemic Risk

- Specify a VAR:

$$\begin{bmatrix} v_{1,t} \\ \vdots \\ v_{Q,t} \end{bmatrix} = \begin{bmatrix} \beta_{0,1} \\ \vdots \\ \beta_{0,Q} \end{bmatrix} + \underbrace{\begin{bmatrix} \beta_{1,1} & \cdots & \beta_{1,Q} \\ \vdots & \ddots & \vdots \\ \beta_{Q,1} & \cdots & \beta_{Q,Q} \end{bmatrix}}_{B^T} \begin{bmatrix} v_{1,t-1} \\ \vdots \\ v_{Q,t-1} \end{bmatrix} + \eta_t$$

$$\eta_t = X_t^T \gamma + \epsilon_t$$

  where $v_{i,t}$ is the Eonia-adjusted, quantity-weighted average WTP of bank i in auction t, and X_t is a vector of controls intended to reflect aggregate shocks (e.g. Bond yields at different maturities).
- Estimation difficulty: Many potential links, but only short panel available.
- Use Machine Learning to "select" the important links: Elastic Net

Using Spillovers of Funding Costs to Quantify Systemic Risk

- Use Elastic Net (Zou 2005):

$$\hat{\theta}_{enet} = \underset{\theta \in \Theta}{\operatorname{argmin}} \|y - Z\theta\|_2^2 \text{ s.t. } (1-\alpha_e)\|\theta\|_2^2 + \alpha_e \|\theta\|_1 \leq \lambda$$

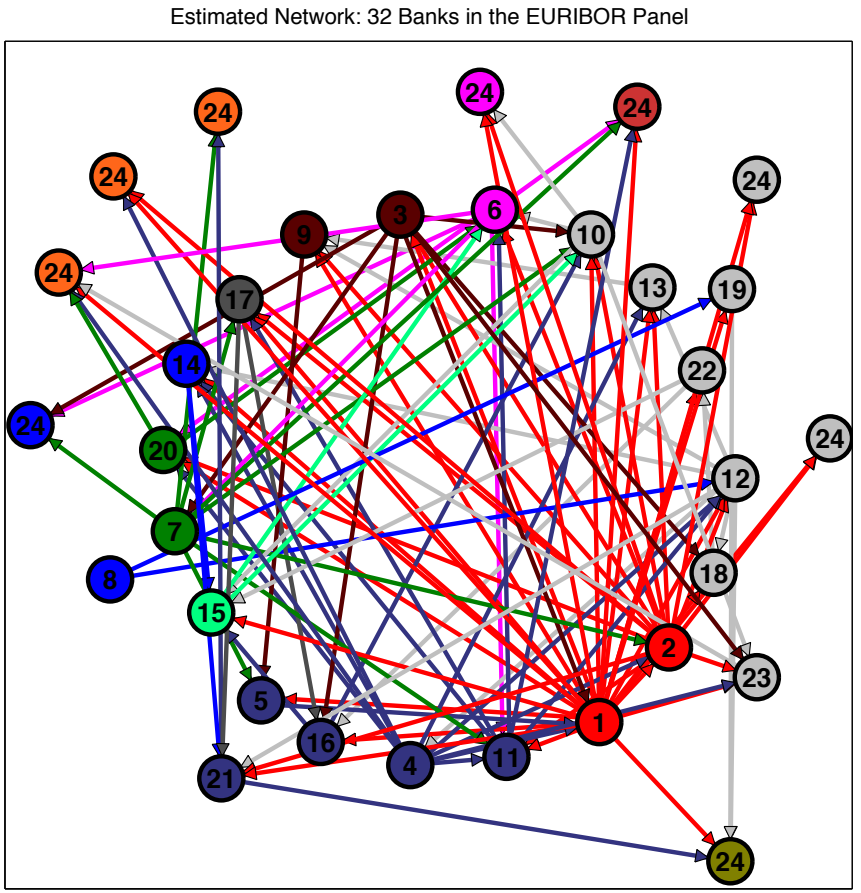
  where the two extreme cases are LASSO ($\alpha_e = 1$) and Ridge regression ($\alpha_e = 0$).
- results in a sparse matrix B, which defines a weighted directed graph.
- Katz centrality can be generalized for weighted networks:

$$k_i^c(\delta) = \sum_{s=1}^{\infty} \sum_{j=1}^{N} \delta^s \left(B^s\right)_{i,j}$$

Interpretation

- Assuming stationarity, let $K = \sum_{s=1}^{\infty} B^s = (I - B)^{-1} - I$.
- Systemicness: $k_j^s = \frac{1}{Q} \sum_i K_{i,j}$ measures the average effect on all banks' WTP of an exogenous shock to j's WTP
- Vulnerability: $k_i^v = \frac{1}{Q} \sum_j K_{i,j}$ measures the average effect on i's WTP of an exogenous aggregate shock to all bank's WTP.
- These measures coincide with Katz centrality (for $\delta = 1$).

Core-periphery



- Color: country, Number: Katz centrality ranking

Systemic Risk Results

- Most banks in the Euro-zone seem to have only weak links, but few banks are quite central. A 100bp shock to these top banks might result in a significant increase to funding costs of other banks (up to the same order of magnitude for some banks).
- Vulnerability measures are correlated with actual subsequent (out of sample) bailouts
- Using weekly bidding data has many advantages over many other methods in the literature which rely on infrequent (and perhaps not very reliable) balance sheet data or stock market data.

Demand System for Financial Assets

- What would happen to price or quantity demanded of 1-m tbill if the treasury were to double the supply of 10-year notes?
- We would like to know (long-run) demand elasticity and substitution patterns between the various instruments.
- Krishnamurthy and Vissing-Jorgensen (JPE 2012): use observed p-q and estimate demand elasticity by utilizing supply shocks
- Koijen and Yogo (wp 2015): BLP-style differentiated product setup
- Hortaçsu and Kastl (in progress): AIDS model using mutual funds and insurance filings together with the auction-level estimates of short-run demand curves

Papers with IO methods on other financial markets

- Snyder and Youle (2009) - collusion in LIBOR
- Kawai, Onishi and Uetake (2014) - signaling in online credit markets
- Egan, Hortacsu, Matvos (2014) - bank runs
- Crawford, Pavanini and Schivardi (2015) - lending markets

Conclusion

- Financial markets are a great place for IO tools to be applied.
- Many auction markets, for which theory has been tremendously successful, can be studied to gain insight about other markets.
- Using a model to account for the strategic component in observed variables is important for proper interpretation
- There are many open questions!