Pairwise Trading in the Money Market during the European Sovereign Debt Crisis

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Workshop on money markets, monetary policy implementation and central bank balance sheets

EUROPEAN CENTRAL BANK

The views expressed in the paper are solely those of the author and do not necessarily represent the views of the Bank of Italy or the Eurosystem.

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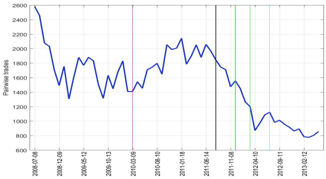
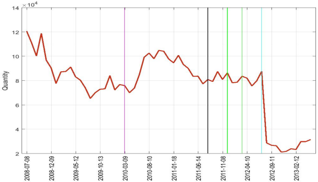
Motivation

- Banks keep reserves at the central bank
  - to manage the reserve requirement, settle transactions and earn interests.
- The unsecured money market was the most important channel to reallocate liquidity
  - before the recent financial crises.
- Crucial market for monetary policy, banking theory and the economics of payments.
- Average rates in this market (EURIBOR, EONIA, ..) affect banks decisions concerning loans to businesses and families,
  - making it crucial also for macroeconomics and finance.
- Great attention was paid to the variation of money market aggregate outcomes during the recent sovereign debt crises.

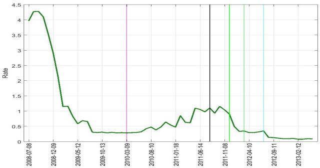
Aggregate Evidence $[y_t]$



(a) Number of trades



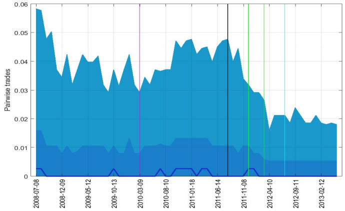
(b) Total quantity exchanged



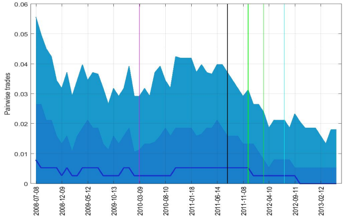
(c) Average rate

Market Side Evidence $[y_{l/b,t}]$

Number of trades



(d) Lenders

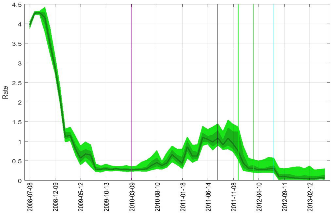


(e) Borrowers

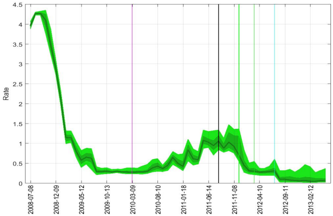
Median, Interquartile range (dark shades), Interdecile range (light shades)

Market Side Evidence [$y_{l/b,t}$]

Rates



(f) Lenders



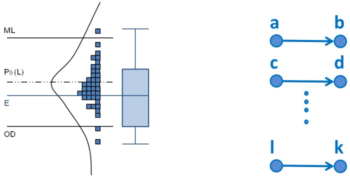
(g) Borrowers

Median, Interquartile range (dark shades), Interdecile range (light shades)

Pairwise Evidence $[y_{ij,t}]$?

OTC Market

- Decentralized market, not anonymous bilateral trades.



- Aggregate figures are functions of pairwise outcomes.
  $EONIA_t = E[p_{ij,t}]$, $trading\ volume_t = N_t * E[q_{ij,t}]$.
- $y_{ij,t} = f(x_{i,t}, x_{j,t}, \beta)$, $y_{ij,t} = p_{ij,t}, q_{ij,t}, l_{ij,t}$.
- Scope of this paper: estimate β
- But first, how to estimate β?

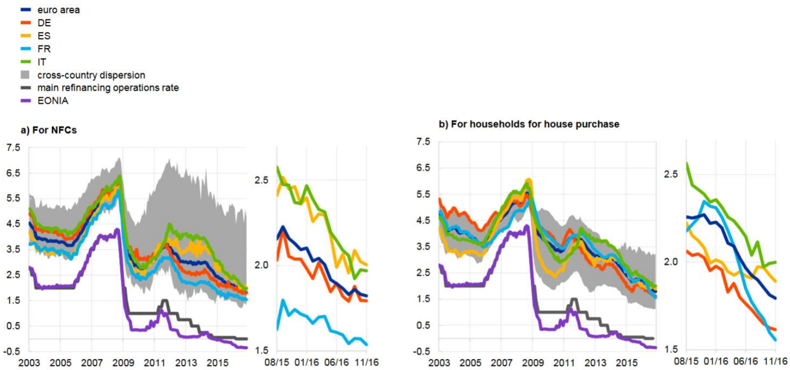
Why are these βs so important?

- Assess European market **fragmentation** (de Andoain et al., 2014; Mayordomo et al., 2015), **segregation** or **integration**, as well as explaining **rate dispersion** (Gaspar et al., 2008) and **supply concentration**, for instance.
- This is an important issue when banks are highly heterogeneous and belong to different nations. An high fragmentation may prevent a **smooth and homogeneous pass-through mechanism**.

ECB Economic Bulletin (1-17)

Composite indicator of the cost of borrowing for NFCs and for households for house purchase

(percentages per annum)



Sources: ECB and ECB calculations.
Notes: The indicator for the total cost of lending is calculated by aggregating short and long-term rates using a 24-month moving average of new business volumes. The cross-country dispersion displays the minimum and maximum range over a fixed sample of 12 euro area countries. The latest observation is for November 2016.

Related Literature

- Empirical and theoretical literature on **liquidity hoarding and counterparty credit risk**, see Afonso et al. (2011), Angelini et al. (2011), Heider et al. (2015), Caballero and Krishnamurthy (2008), Acharya and Skeie (2011);
- Large number of theories proposed to explain the features of bilateral trades in **OTC markets** (see Afonso and Lagos, 2015; Bech and Monnet, 2016; Blasques et al., 2016; Duffie et al., 2005, among the others);
- The empirical literature still lacks in providing **formal econometric models and evidences** to better understand these pairwise outcomes.

Contribution

- Empirical analysis (estimate β):
  Trading outcomes in the unsecured money market during the European sovereign debt crisis;
  - Role of **nationality** and **balance sheet structure** on the probability to trade, and on bilateral rates and quantities.
- Econometric modelling (how to estimate β):
  Dyadic econometric model with shadow rates.

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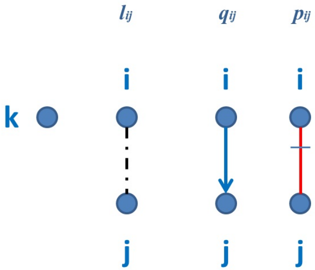
A Decentralized Market with Counterparty-risk Uncertainty

$$y_{ij,t} = f(x_{i,t}, x_{j,t}, \beta),\ y_{ij,t} = l_{ij,t}, q_{ij,t}, p_{ij,t}.$$



- l_{ij} A link is possible under a non-random meeting process
- q_{ij} The exchanged quantity is influenced by non-random liquidity shocks
- p_{ij} The rate reflects non-random monitoring and searching costs or default risk

Non-random unobservable features

Monitoring, Searching and Last Resort Counterparty

Suppose that the central bank sets a interest rate corridor with p_{OD} and p_{ML}

Borrower payoff

$$\pi_b = p_{ML} - (p_{lb} + s_{b,l}) \tag{1}$$

Lender payoff

$$\pi_l = i_{lb}(\hat{PD}_l(b)) - m_{l,b} - s_{l,b} - p_{OD} \tag{2}$$

Suppose bank i receives an exogenous liquidity shock ξ_i that may represent client's payments or cash withdrawals.

Nash equilibrium interest rate and the liquidity exchanged

$$\tilde{p}_{lb} = argmax\ f(\pi_l, \pi_b, \mu_l, \mu_b, w_{lb}) \tag{3}$$

$$\tilde{q}_{lb} = argmax\ h(\xi_l, \xi_b, y_{lb}) \tag{4}$$

- μ_l and μ_b are the borrower and lender bargaining powers;
- w_{lb} and y_{lb} are sets of observable and unobservable pair-specific characteristics.

see Blasques et al. (2016)

A Dyadic Econometric Model with Shadow Rates

Suppose that the **rate function** is linear in its arguments

$$p_{lb} = \beta_0 + \beta_1 x_{lb} + \alpha q_{lb} + \epsilon_{lb}, \tag{5}$$

observed if only if $\pi_l \geq 0 \cap \pi_b \geq 0$.

Let bank j have two **shadow rates** one as lender and one as borrower, $p^*_{L,jk}$ and $p^*_{B,jk}$ respectively,

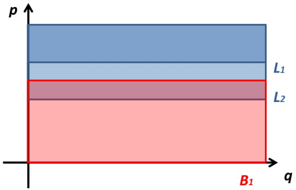
$$p^*_{B,b} = \theta_{0l} + \theta_1 z_{lb} + \theta_{2b} q_{lb} + \theta_3 k_b + u_B, \tag{6}$$

$$p^*_{L,l} = \gamma_{0b} + \gamma_1 z_{lb} + \gamma_{2l} q_{lb} + \gamma_3 k_l + u_L. \tag{7}$$

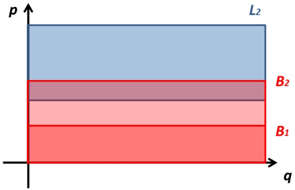
A loan and its rate are observed if $I(p_{lb} \geq p^*_{L,l}) I(p^*_{B,b} \geq p_{lb}) = 1$.

A Dyadic Econometric Model with Shadow Rates

Each pair of banks is thus characterized by a **plausible rate-quantity region**, that is the intersection between the two areas respectively upper and lower-countered by (6) and (7).



(h) Supply intercept



(i) Demand intercept

A Dyadic Econometric Model with Shadow Rates

$$\begin{gathered} p_{lb} = p^*_{lb} s_l s_b, \\ p^*_{lb} = \beta_0 + \beta_1 x_{lb} + \alpha q_{lb} + \epsilon_{lb}, \\ s_l = I(s^*_l \geq 0), \\ s_b = I(s^*_b \geq 0), \\ s^*_l = \omega r_l + v_L, \\ s^*_b = \lambda r_b + v_B, \\ (\epsilon_{lb}, v_B, v_L) \sim f\left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_\epsilon & \sigma_{\epsilon v_B} & \sigma_{\epsilon v_L} \\ \sigma_{\epsilon v_B} & \sigma_{v_B} & \sigma_{v_B v_L} \\ \sigma_{\epsilon v_L} & \sigma_{v_B v_L} & \sigma_{v_L} \end{bmatrix} \right), \end{gathered} \tag{8}$$

$$E[p_{lb} | s_b = 1, s_l = 1] \quad = \quad \beta_0 + \beta_1 x_{lb} + \alpha q_{lb} + E[\epsilon_{lb} | s_b = 1, s_l = 1], \tag{9}$$

where $E[\epsilon_{lb} | s_b = 1, s_l = 1]$ may be different from zero, generating the **selectivity bias**.

Estimators

- **Parametric Estimation** (multivariate Mills ratios)

$$
\begin{aligned}
E[p_{lb}|s_b = 1, s_l = 1] &= \beta_0 + \beta_1 x_{lb} + \alpha q_{lb} \\
&+ \frac{\sigma_{\epsilon v_B}}{\sigma^2_{v_B}} \frac{\phi(\kappa^* r_b)\Phi((\omega^* r_l - \rho_{v_B v_L}\kappa^* r_b)/(1-\rho^2_{v_B v_L})^{\frac{1}{2}})}{\mathbf{\Phi}^2(\kappa^* r_b, \omega^* r_l, \rho_{v_B v_L})} \\
&+ \frac{\sigma_{\epsilon v_L}}{\sigma^2_{v_L}} \frac{\phi(\omega^* r_l)\Phi((\kappa^* r_b - \rho_{v_B v_L}\omega^* r_l)/(1-\rho^2_{v_B v_L})^{\frac{1}{2}})}{\mathbf{\Phi}^2(\kappa^* r_b, \omega^* r_l, \rho_{v_B v_L})},
\end{aligned}
\tag{10}
$$

- **Semiparametric Estimation** (power series)

$$
E[p_{lb}|s_b = 1, s_l = 1] = \beta_0 + \beta_1 x_{lb} + \alpha q_{lb} + \sum_{k=1}^{q} \gamma_k \tau_{lb}^{k-1}. \tag{11}
$$

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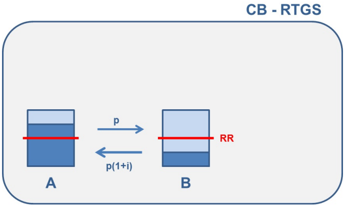
Data Challanges

- **Bilateral Trades**
  - Representative sample of interbank loans in euro
  - No complete statistical archive
    - EONIA panel
    - e-MID
    - Spanish MID
    - Data on Greek banks
    - T2
  - Solved with money market statistical reporting (MMSR)?
- **Banks Characteristics**
  - Include meaningful information
  - Banks operating in euro, but not necessarily European
    - Bankscope
    - SNL
- **International Groups Structures**
  - Lots of CBmoney moved intragroup
  - Need of word-wide group structure
    - SWIFT BIC directory

Data

Bilateral Trades

The market for CB money is generated by the reserve requirement and liquidity needs (on the demand side) and has CB RTGS system as an institutionally designed support, as standard in modern economic systems.



From **TARGET2** data we can identify loans applying the Furfine (1999) algorithm, see Arciero et al. (2016) (or Frutos et al. (2016) ?) when i is strictly positive and Rainone and Vacirca (2015) when they can be zero or negative.

Banks Characteristics

Balance sheet composition from Bankscope

Maintenance period		2009-03-11 - 2009-04-07			
Variable	Description	mean	std	min	max
Loan					
Rate	Interest rate paid	0.83	0.20	0.21	2.50
Quantity	Quantity exchanged (millions)	16.19	53.42	0.05	1033.16
Lender					
A loan	Loans expressed as percentages of lender total assets	0.57	0.20	0.00	0.90
A fix as	Fixed assets expressed as percentages of lender total assets	0.01	0.01	0.00	0.14
A non ern	Non -earning assets expressed as percentages of lender total assets	0.07	0.07	0.00	0.96
L dep sh fun	Deposits and short-term funding expressed as percentages of lender total assets	0.62	0.17	0.00	0.99
L oth int bea	Other interest bearing liabilities expressed as percentages of lender total assets	0.25	0.17	0.00	0.87
L oth res	Other reserves expressed as percentages of lender total assets	0.01	0.01	0.00	0.13
L equ	Equity expressed as percentages of lender total assets	0.08	0.04	0.00	0.60
A tot asset	Total assets expressed in millions of euros	10.00	2.22	3.06	14.54

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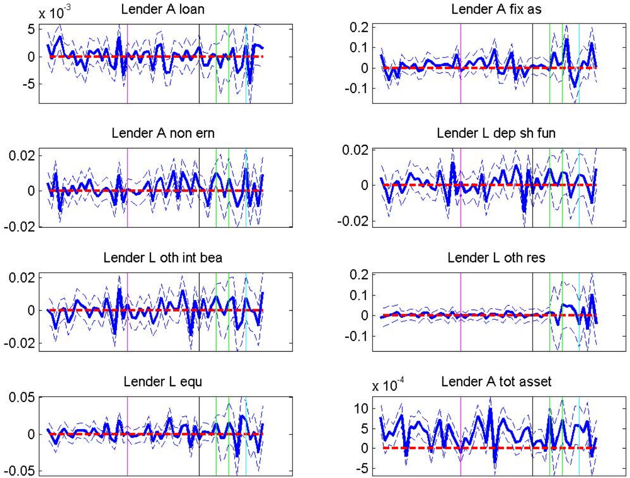
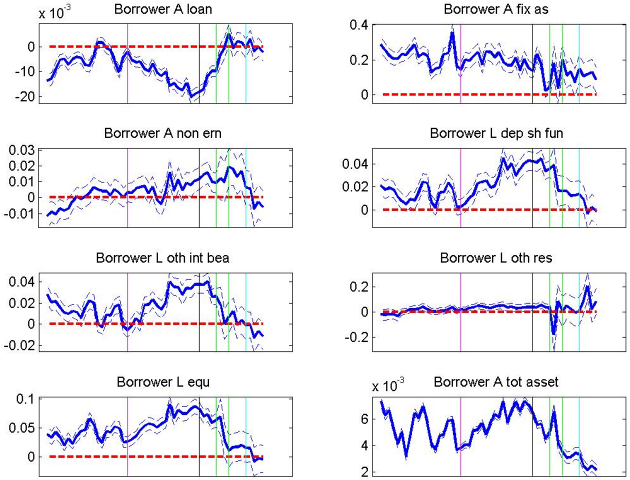
Set up

- **Repeated cross section**
  - each maintenance period
  - lagged controls (previous activity and links)
- **1st step**: link formation (shadow rate equations)
- **2nd step**: rates and quantities
  - correction for potential endogeneity
- **Graphical representation**
  - Balance sheet
  - Nationality

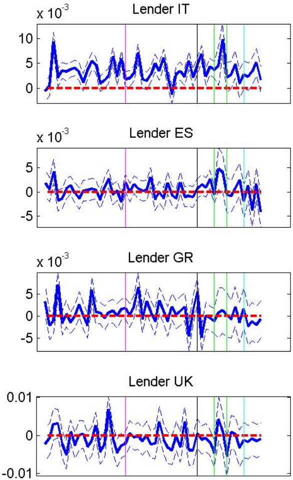
1st Step - Probability to trade - Lender balance sheet



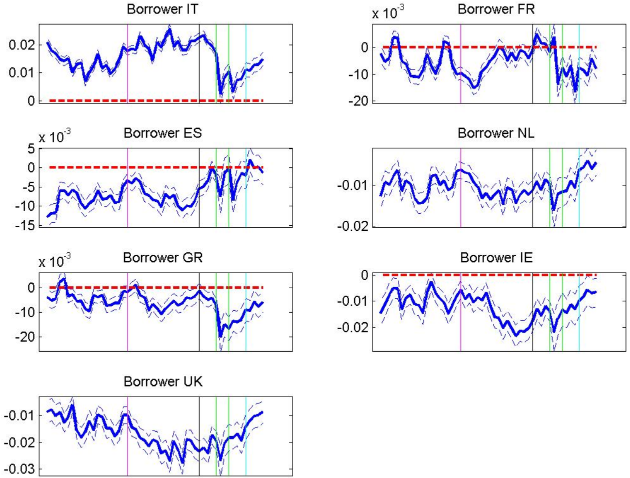
1st Step - Probability to trade - Borrower balance sheet



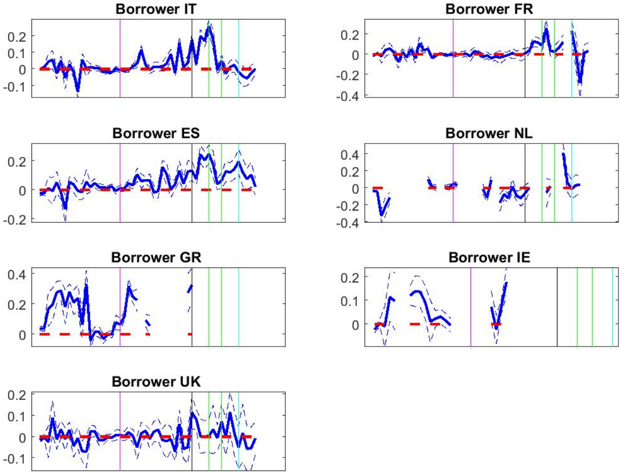
1st Step - Probability to trade - Lender nationality



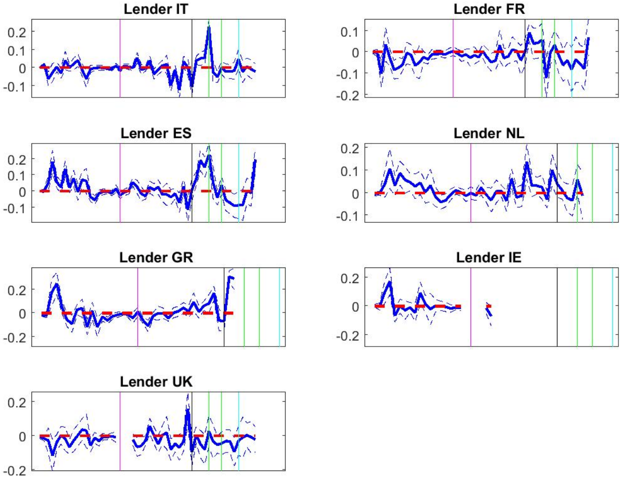
1st Step - Probability to trade - Borrower nationality



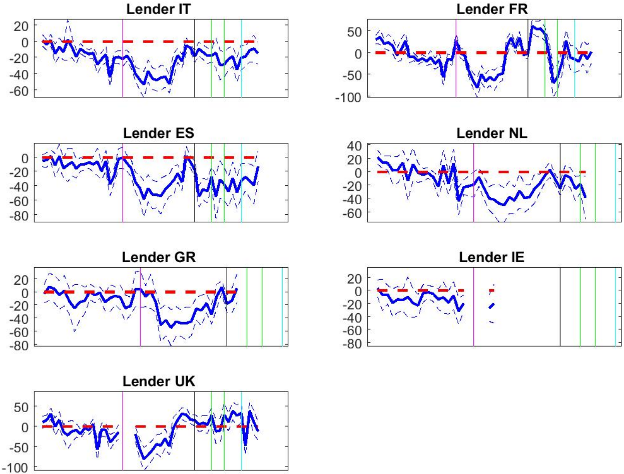
Rates - Borrower nationality



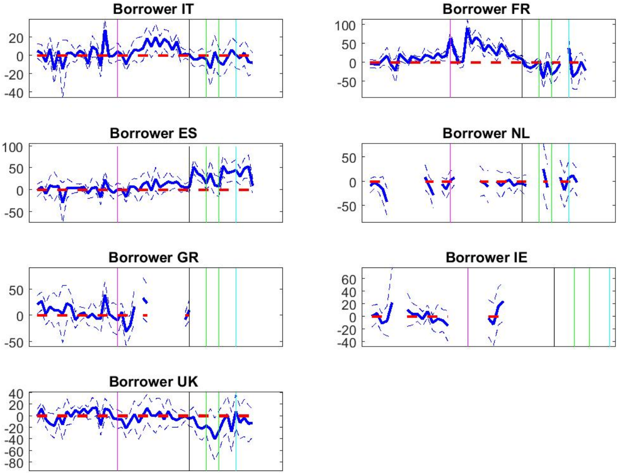
Rates - Lender nationality



Quantities - Lender nationality



Quantities - Borrower nationality



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- **Dyadic model with shadow rates**
  - **Joint analysis** of link formation, rates and quantities
  - Against bias when **counterparties endogenously select each other** (monitoring and searching costs).
  - **Few parameters impacted**, but necessary.

- Study the **trade patterns during the European debt crises**.
  - **Before the Eurosystem LTROs**, we found that
    - **Decreased market access to low equity and illiquid borrowers** (Coherent with lenders' active monitoring)
    - **Dispersion in rates is mainly driven by borrowers' nationality**
    - **Differential liquidity rationing explained by lenders' nationality**

Extensions and limits

- **Extensions**
  - **Bilateral $\rightarrow$ Multilateral**;
    - to mimic a portfolio choice problem
    - to fit better the interbank network topology
  - **Endogenizing the quantities**;
  - **Not linear specification**;
  - **Including more pair-specific variables**.
    - to capture homophilic behavior
    - to explain better the matching process
  - **Model time and network dimensions jointly**
- **Limits**
  - **One market** perspective (partial equilibrium)
  - Rely on **exclusion restrictions**
  - **Estimated microstructure** (Furfine algo)
  - Imperfect **info on balance sheet** structure
  - No **info on searching and matching** process
  - **Missing time line** from trade to settlement
  - **Aggregation** criterion

THANK YOU!

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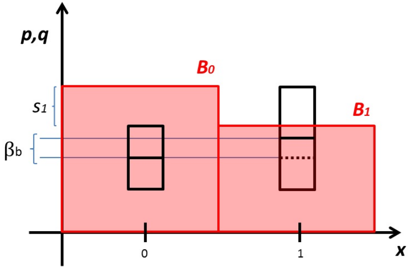
Appendix

A Simple Example with Unobservable Costs

- $x_b = \{0, 1\}$, 1 if the borrower is in country A, $\beta_b > 0$ (riskier).
- Searching costs are different from zero only for banks in country A -i.e. $s_1 > s_0 = 0$-. Rates for country A are upper bounded.
- ϵ_{lb} is correlated with s_b.

Endogenous Borrower Searching Costs



- $E(p_{lb}|x_b = 0) - E(p_{lb}|x_b = 1)$ is zero instead of β_b.

Empirical Specification

- Repeated cross-section of first and second stage for each MP,
- Parametric estimator as default,
- To ease the computational burden we assume that θ_{2b} and γ_{2l} are equal to zero,
- Outcome controls: $x_{bl,t} = [B_{l,t}, C_{l,t}, B_{b,t}, C_{b,t}, g_{lb,t-1}]$,
- Selection equation controls: $z_{bl,t} = [B_{l,t}, C_{l,t}, B_{b,t}, C_{b,t}]$, $k_b = [\bar{p}^B_{b,t-1}, q^B_{b,t-1}, n^B_{b,t-1}]$, $k_l = [\bar{p}^L_{l,t-1}, q^L_{l,t-1}, n^L_{l,t-1}]$.
- $B_{i,t}$ and $C_{i,t}$ contain respectively the information about the balance sheet structure and nationality of bank i at time t.
- $g_{ij,t-1}$ is equal to 1 whether a loan with i as borrower and j as lender was observed at time $t-1$,
- $\bar{p}^B_{i,t}$ and $\bar{p}^L_{i,t}$ are the average rates experienced respectively as borrower and as lender at time t by bank i, while $q^B_{i,t}$ and $q^L_{i,t}$ are the values exchanged respectively as borrower and as lender at time t by the bank i.
- $n^B_{i,t}$ and $n^L_{i,t}$ are the number of counterparties respectively as borrower and as lender at time t by the bank i.
- These last three variables can be powerful explanatory variables respectively for borrower and lender shadow rates and work as exclusion restrictions in the estimation process. The presence of many financial crises during the time span considered provides frequent exogenous shocks to banks' shadow rates. For example, many lenders left the market suddenly.

Banks Characteristics

Group Structure and Head Nationality from SWIFT directory

Maintenance period		2009-03-11 - 2009-04-07			
Variable	Description	mean	std	min	max
IT	Dummy variable taking value equal to 1 if the lender is from this country (or set of countries) and zero otherwise.	0.44	0.50	0.00	1.00
FR	""	0.05	0.21	0.00	1.00
ES	""	0.05	0.22	0.00	1.00
NL	""	0.03	0.16	0.00	1.00
GR	""	0.03	0.16	0.00	1.00
IE	""	0.02	0.13	0.00	1.00
UK	""	0.02	0.13	0.00	1.00
US/JAP/EX	""	0.03	0.16	0.00	1.00
AT	""	0.06	0.24	0.00	1.00
PT	""	0.04	0.19	0.00	1.00
LU	""	0.01	0.11	0.00	1.00
CY	""	0.01	0.11	0.00	1.00
CH	""	0.00	0.07	0.00	1.00
FI	""	0.00	0.06	0.00	1.00
EUEX	""	0.08	0.27	0.00	1.00
BE	""	0.00	0.06	0.00	1.00

Time span

from may 2008 to the end of 2012

Snapshot (2010-01-20 - 2010-02-09) - Quantities

	Simple regression		Selection correction		T-stat difference	
Mills Borrower			-115.0199***			
			(23.9951)			
Mills Lender			-85.5174 ***			
			(17.8718)			
	Lender	Borrower	Lender	Borrower	Lender	Borrower
A loan	6.3986	-6.1036	-0.8143	**-14.1645 ***	0.6512	0.6644
	(7.8825)	(8.6316)	(7.7816)	**(8.5254)**	[0.7425]	[0.7467]
A fix as	-205.9081	-214.8743	-144.4210	-27.0155	-0.2707	-0.7261
	(161.9778)	(183.5641)	(159.2448)	(182.3413)	[0.3933]	[0.2340]
A non ern	66.8535 **	-67.6508 **	73.2480 ***	-72.5851 **	-0.1600	0.1076
	(28.5485)	(32.7724)	(27.9638)	(32.0641)	[0.4365]	[0.5428]
L dep sh fun	34.8874	-44.4600	18.3525	-19.3109	0.4476	-0.6039
	(26.3047)	(29.4818)	(25.9386)	(29.4155)	[0.6727]	[0.2730]
L oth int bea	34.4045	-37.5091	30.1779	-23.8505	0.1122	-0.3289
	(26.9349)	(29.5910)	(26.3464)	(29.1361)	[0.5446]	[0.3711]
L oth res	-94.2805	-464.5184	-26.2109	-478.2933	-0.1601	0.0284
	(303.8844)	(346.9461)	(297.3783)	(339.3746)	[0.4364]	[0.5113]
L equ	26.2915	55.8195	15.5751	42.4104	0.1941	0.1410
	(39.4601)	(67.9548)	(38.6153)	(66.5232)	[0.5769]	[0.5561]
A tot asset	0.8051	0.2353	**-1.7011 ***	**-1.8950 ***	1.9349	1.3480
	(0.8898)	(1.1078)	**(0.9412)**	**(1.1271)**	[0.9734]	[0.9110]

	Simple regression		Selection correction		T-stat difference	
IT	-5.3730	2.1513	-0.8136	**10.9651** *	-0.5891	-0.9788
	(5.5120)	(6.3591)	(5.4327)	**(6.3753)**	[0.2780]	[0.1640]
FR	6.4208	9.6956	-7.8743	**35.6712** ***	1.2724	-1.8280
	(7.8721)	(9.4197)	(8.0154)	**(10.6393)**	[0.8982]	[0.0339]
ES	7.3184	-9.9276	8.7138	-9.1562	-0.1092	-0.0625
	(9.1304)	(8.8161)	(8.9429)	(8.6224)	[0.4565]	[0.4751]
NL	0.1365	-20.6351	-7.6851	-15.2179	0.5706	-0.3066
	(9.7475)	(12.6118)	(9.6375)	(12.3784)	[0.7158]	[0.3796]
GR	10.7974	-10.2980	10.9168	-5.7408	-0.0050	-0.1782
	(17.1602)	(18.2703)	(16.7803)	(17.8894)	[0.4980]	[0.4293]
UK	9.5135	-8.0704	1.9895	-11.9184	0.4623	0.2885
	(11.5314)	(9.5098)	(11.4826)	(9.3498)	[0.6780]	[0.6135]
US/JAP/EX	-0.8014	9.2517	-0.5150	14.4930	-0.0193	-0.2810
	(10.5874)	(13.3213)	(10.3590)	(13.0572)	[0.4923]	[0.3894]
AT	-2.7670	-5.0445	1.7754	-0.4491	-0.5499	-0.4910
	(5.8758)	(6.6712)	(5.8060)	(6.5636)	[0.2913]	[0.3118]
PT	5.3247	-22.1638 **	7.1816	**-14.7469**	-0.1513	-0.5494
	(8.7659)	(9.5934)	(8.5896)	**(9.4998)**	[0.4399]	[0.2914]
CY		-27.2089		-18.2724		-0.3817
		(16.7152)		(16.3943)		[0.3514]
EUEX	-0.9160	-22.6624 ***	-1.4285	-16.1408 **	0.0535	-0.5929
	(6.8343)	(7.8358)	(6.7206)	(7.7185)	[0.5213]	[0.2767]
Rates at t-1	-2797.4123 *	1946.0673	-2922.3237 *	733.2042	0.0557	0.5280
	(1601.9363)	(1630.5859)	(1566.9273)	(1618.2008)	[0.5222]	[0.7012]
Value at t-1	0.0546 ***	0.0203 ***	0.0395 ***	**-0.0261** **	2.5184	3.5207
	(0.0037)	(0.0066)	(0.0048)	**(0.0114)**	[0.9940]	[0.9998]
# counterparts at t-1	1.4814	-1.8501	0.9372	-1.2246	0.3077	-0.3441
	(1.2597)	(1.2955)	(1.2412)	(1.2749)	[0.6208]	[0.3654]
Connection at t-1	13.4627 ***		12.9965 ***		0.1194	
	(2.7910)		(2.7323)		[0.5475]	
$\bar{R}^2$	0.3402		0.3692			
Time interval			2010-01-20 - 2010-02-09			
Maturity			1 to 3 days			
Observations			1067			

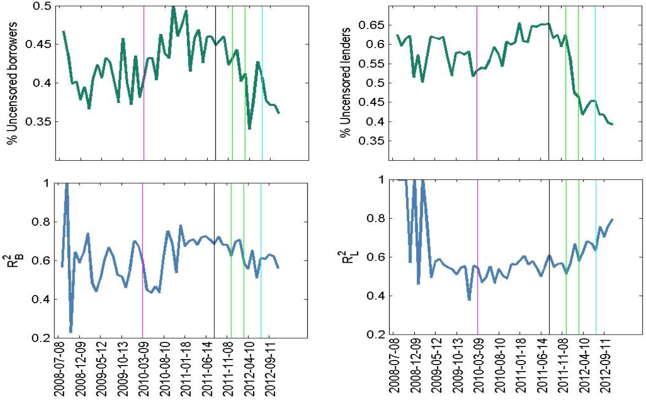
Snapshot (2010-01-20 - 2010-02-09) - Rates

	Simple regression		Selection correction		T-stat difference	
Mills Borrower			0.0398**			
			(0.0163)			
Mills Lender			0.0475***			
			(0.0182)			
	Lender	Borrower	Lender	Borrower	Lender	Borrower
A loan	0.0163	-0.0460 ***	0.0145	-0.0396 ***	0.0841	-0.0298
	(0.0133)	(0.0145)	(0.0136)	(0.0149)	[0.5335]	[0.4881]
A fix as	0.2910	0.9290 ***	0.3530	1.0132 ***	-0.2312	-0.4014
	(0.2739)	(0.2981)	(0.2753)	(0.3061)	[0.4086]	[0.3441]
A non ern	0.1006 **	-0.0532	0.1114 **	-0.0619	0.0468	-0.0175
	(0.0488)	(0.0554)	(0.0491)	(0.0570)	[0.5187]	[0.4930]
L dep sh fun	0.1067 **	0.0345	0.1316 ***	0.0327	-0.2102	-0.0476
	(0.0444)	(0.0487)	(0.0452)	(0.0526)	[0.4168]	[0.4810]
L oth int bea	0.0461	0.0573	0.0689	0.0556	-0.0939	-0.1052
	(0.0458)	(0.0491)	(0.0467)	(0.0535)	[0.4626]	[0.4581]
L oth res	-0.0826	-0.4602	0.1963	-0.6389	-0.1107	0.1622
	(0.5045)	(0.5828)	(0.5165)	(0.5985)	[0.4559]	[0.5644]
L equ	0.0258	0.3316 ***	0.0457	0.3033 **	-0.1446	0.0104
	(0.0667)	(0.1155)	(0.0677)	(0.1177)	[0.4425]	[0.5042]
A tot asset	0.0066 ***	-0.0052 ***	0.0080 ***	-0.0047 **	-1.2526	-1.1767
	(0.0015)	(0.0018)	(0.0016)	(0.0021)	[0.1053]	[0.1198]

	Simple regression		Selection correction		T-stat difference	
IT	0.0096	0.0011	0.0162 *	-0.0032	-0.3541	0.7159
	(0.0089)	(0.0094)	(0.0094)	(0.0096)	[0.3617]	[0.7629]
FR	-0.0029	-0.0038	-0.0017	0.0020	-0.0252	0.2393
	(0.0131)	(0.0157)	(0.0141)	(0.0219)	[0.4900]	[0.5945]
ES	0.0138	-0.0061	0.0159	-0.0054	0.2196	0.2542
	(0.0156)	(0.0150)	(0.0157)	(0.0152)	[0.5869]	[0.6003]
NL	-0.0128	0.0061	-0.0124	0.0038	-0.1127	0.4059
	(0.0168)	(0.0219)	(0.0170)	(0.0221)	[0.4551]	[0.6576]
GR	-0.0411	0.0784 **	-0.0352	0.0749 **	-0.0169	0.2719
	(0.0296)	(0.0315)	(0.0297)	(0.0316)	[0.4933]	[0.6071]
UK	-0.0079	0.0079	-0.0226	0.0039	-0.0523	0.2362
	(0.0199)	(0.0160)	(0.0212)	(0.0165)	[0.4791]	[0.5933]
US/JAP/EX	-0.0311 *	-0.0294	-0.0345 *	-0.0345	0.2097	0.4740
	(0.0179)	(0.0230)	(0.0183)	(0.0232)	[0.5830]	[0.6822]
AT	-0.0089	-0.0150	-0.0064	-0.0138	0.0799	0.5175
	(0.0099)	(0.0113)	(0.0100)	(0.0114)	[0.5319]	[0.6975]
PT	0.0310 **	0.0566 ***	0.0360 **	0.0561 ***	-0.0056	0.4380
	(0.0145)	(0.0166)	(0.0146)	(0.0167)	[0.4978]	[0.6693]
CY		0.1003 ***		0.0973 ***		0.3012
		(0.0289)		(0.0289)		[0.6183]
EUEX	-0.0104	0.0110	-0.0114	0.0094	0.1273	0.3548
	(0.0116)	(0.0135)	(0.0119)	(0.0142)	[0.5506]	[0.6386]
Constant	0.1089		-0.0734		1.0777	
	(0.0744)		(0.0987)		[0.8593]	
Connection at t-1	-0.0081 *		-0.0076 *		-0.6167	
	(0.0045)		(0.0046)		[0.2688]	
Quantity exchanged	(0.0000		-0.0000		-0.7851	
	(0.0001)		(0.0001)		[0.2163]	
$\bar{R}^2$	0.2080		0.2172			
Time interval			2010-01-20 - 2010-02-09			
Maturity			1 to 3 days			
Observations			1067			

Diagnostics - Mills ratios non linearity

Rate equation. Diagnostics. Mills ratios non linearity and percentages of uncensored lenders and borrowers.



Diagnostics - Functional assumptions

Dependent Variable: bilateral rate

	Parametric		Semiparametric	
	Lender	Borrower	Lender	Borrower
A loan	0.0163	-0.0460 ***	0.0145	-0.0396 ***
	(0.0133)	(0.0145)	(0.0136)	(0.0149)
A fix as	0.2910	0.9290 ***	0.3530	1.0132 ***
	(0.2739)	(0.2981)	(0.2753)	(0.3061)
A non ern	0.1006 **	-0.0532	0.1114 **	-0.0619
	(0.0488)	(0.0554)	(0.0491)	(0.0570)
L dep sh fun	0.1067 **	0.0345	0.1316 ***	0.0327
	(0.0444)	(0.0487)	(0.0452)	(0.0526)
L oth int bea	0.0461	0.0573	0.0689	0.0556
	(0.0458)	(0.0491)	(0.0467)	(0.0535)
L oth res	-0.0826	-0.4602	0.1963	-0.6389
	(0.5045)	(0.5828)	(0.5165)	(0.5985)
L equ	0.0258	0.3316 ***	0.0457	0.3033 **
	(0.0667)	(0.1155)	(0.0677)	(0.1177)
A tot asset	0.0066 ***	-0.0052 ***	0.0080 ***	-0.0047 **
	(0.0015)	(0.0018)	(0.0016)	(0.0021)
IT	0.0096	0.0011	0.0162 *	-0.0032
	(0.0089)	(0.0094)	(0.0094)	(0.0096)
FR	-0.0029	-0.0038	-0.0017	0.0020
	(0.0131)	(0.0157)	(0.0141)	(0.0219)
ES	0.0138	-0.0061	0.0159	-0.0054
	(0.0156)	(0.0150)	(0.0157)	(0.0152)
NL	-0.0128	0.0061	-0.0124	0.0038
	(0.0168)	(0.0219)	(0.0170)	(0.0221)

Diagnostics - Functional assumptions

	Parametric		Semiparametric	
	Lender	Borrower	Lender	Borrower
GR	-0.0411	0.0784 **	-0.0352	0.0749 **
	(0.0296)	(0.0315)	(0.0297)	(0.0316)
UK	-0.0079	0.0079	-0.0226	0.0039
	(0.0199)	(0.0160)	(0.0212)	(0.0165)
US/JAP/EX	-0.0311 *	-0.0294	-0.0345 *	-0.0345
	(0.0179)	(0.0230)	(0.0183)	(0.0232)
AT	-0.0089	-0.0150	-0.0064	-0.0138
	(0.0099)	(0.0113)	(0.0100)	(0.0114)
PT	0.0310 **	0.0566 ***	0.0360 **	0.0561 ***
	(0.0145)	(0.0166)	(0.0146)	(0.0167)
CY		0.1003 ***		0.0973 ***
		(0.0289)		(0.0289)
EUEX	-0.0104	0.0110	-0.0114	0.0094
	(0.0116)	(0.0135)	(0.0119)	(0.0142)
Connection at $t-1$	-0.0081 *		-0.0076 *	
	(0.0045)		(0.0046)	
Quantity exchanged	0.0000		-0.0000	
	(0.0001)		(0.0001)	
Constant	0.1089		-0.0734	
	(0.0744)		(0.0987)	
Time interval	2010-01-20 - 2010-02-09			
Maturity	1 to 3 days			
Observations	1067			

Diagnostics - Exclusion restrictions

Dependent Variable: estimated residuals

	Rate equation			Quantity equation		
	Simple regression	Selection correction	Δ	Simple regression	Selection correction	Δ
Borrower rates at $t-1$	4.6453 ***	4.3973 **	0.0710	-0.0000	0.0000	-0.0000
	(1.7471)	(1.7450)	(0.4717)	(1030.8095)	(1006.9246)	(0.5000)
Borrower value at $t-1$	-0.0000 ***	-0.0000 *	-0.4401	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.3300)	(0.0040)	(0.0039)	(0.5000)
Borrower # of cntrprts $t-1$	-0.0034 **	-0.0032 **	-0.0820	0.0000	-0.0000	0.0000
	(0.0014)	(0.0014)	(0.4673)	(0.8129)	(0.7940)	(0.5000)
Lender rates at $t-1$	12.9894 ***	12.4827 ***	0.1156	-0.0000	-0.0000	-0.0000
	(2.1933)	(2.1905)	(0.4540)	(1294.0245)	(1264.0406)	(0.5000)
Lender value at $t-1$	-0.0000	0.0000	-0.2960	0.0000	0.0000	-0.0000
	(0.0000)	(0.0000)	(0.3837)	(0.0031)	(0.0030)	(0.5000)
Lender # of cntrprts $t-1$	-0.0107 ***	-0.0101 ***	-0.1677	0.0000	0.0000	0.0000
	(0.0017)	(0.0017)	(0.4334)	(1.0158)	(0.9923)	(0.5000)
Time interval	2010-01-20 - 2010-02-09					
Maturity	1 to 3 days					
Observations	1067					

Estimation with False Positive

The rate equation in vector terms:

$$P = \beta_0 + \beta_1 X + \epsilon, \tag{12}$$

Suppose loans can be split in true and false, then $P = [P_T'; P_F']'$ and $X = [X_T'; X_F']'$ and

$$P_T = \beta_{0,T} + \beta_{1,T} X_T + \epsilon_T, \tag{13}$$

$$P_F = \beta_{0,F} + \beta_{1,F} X_F + \epsilon_F, \tag{14}$$

For $\hat{\beta}_{OLS}$ to be a consistent estimator of $\beta_T = [\beta_{0,T}'; \beta_{0,F}']'$ we need the following assumptions.
A1 $\beta_F = \beta_T$
A2 $E(X_T \epsilon_T) = E(X_F \epsilon_F) = 0$

If the algorithm is randomly picking false loans across pairs of banks, it is plausible to think that the relationship between X, Y and ϵ is not structurally different between the true loans subpopulation and the whole sample.
A1 and A2 are less strong assumptions, they allow for systematic inclusion of pairs of banks in the sample as long as they are associated with random rates. Bias emerges when the pair is systematically wrongly included and associated with non random rates.
We aggregate loans across the maintenance period, thus our variables are less prone to measurement error.