A Dynamic Network Model of the Unsecured Interbank Lending Market

Falk Bräuning[a] Francisco Blasques[a] Iman van Lelyveld[b]

[a]VU University Amsterdam & Tinbergen Institute
[b]De Nederlandsche Bank & Bank for International Settlements

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- Policy analysis: role of central bank corridor

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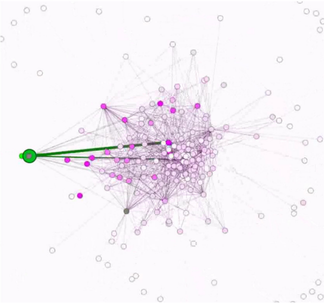
Dutch Interbank Market during Crisis



Before Lehman 08/2008

Figure : **Nodes:** banks; **links:** ON loans; **big green node:** central bank; **small green nodes:** banks only relying on central bank; **pink nodes:** banks without use of central bank facilities, see video 3 Heijmans et al. (2014)

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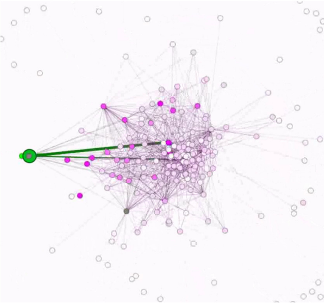

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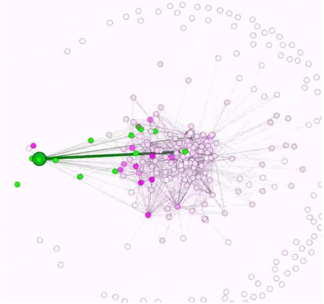

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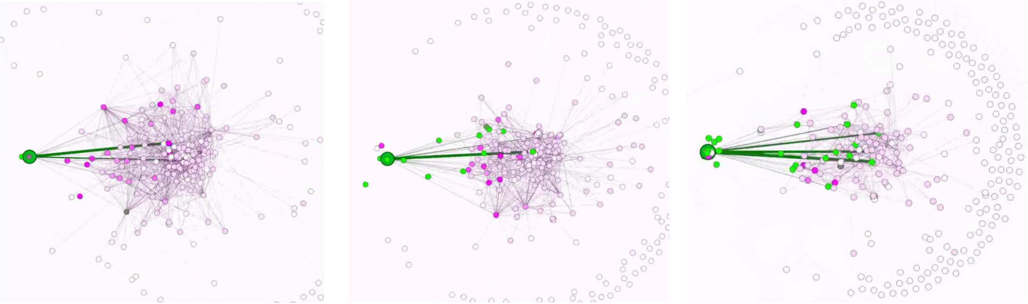

Before Lehman 08/2008 | After Lehman 12/2008 | After 3yr LTRO 12/2011

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Relevance of Private Information

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$\rightarrow$ **Key issue**: Role of credit risk uncertainty, peer monitoring and private information in the interbank market? We need to consider uncertainty as bank-to-bank specific problem!

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Liquidity Shocks

- Network of N banks $i = 1, ..., N$, time is discrete and infinite
- Banks are hit by liquidity shocks $\zeta_{i,t}$

$$\zeta_{i,t} \overset{iid}{\sim} \mathcal{N}(\mu_{\zeta_i}, \sigma^2_{\zeta_i}) \quad \text{where } \ \mu_{\zeta_i} \sim \mathcal{N}(\mu_\mu, \sigma^2_\mu) \ \text{ and } \ \log \sigma_{\zeta_i} \sim \mathcal{N}(\mu_\sigma, \sigma^2_\sigma)$$

and correlation parameter $\rho_\zeta := corr(\mu_{\zeta_i}, \log \sigma_{\zeta_i})$, heterogeneity related to scale of bank's business (σ_{ζ_i}) and structural liquidity supply or demand (μ_{ζ_i})

- Banks can smooth liquidity shocks by either

- recourse to central bank facilities with borrowing rate $\overline{r}_t$ and deposit rate $\underline{r}_t$, where $\overline{r}_t > \underline{r}_t$ OR
- unsecured interbank lending under asymmetric info about counterparty risk
  - counterparty selection
  - bilateral interest rate bargaining

Credit Risk Uncertainty and Peer Monitoring

- Perceived financial distress $z_{i,j,t}$

$$z_{i,j,t} = z_{j,t} + e_{i,j,t}$$

where $z_{j,t} \sim (0, \sigma^2)$ is true financial distress with true prob of default $\mathbb{P}(z_{j,t} > \epsilon)$ and $e_{i,j,t} \sim (0, \tilde{\sigma}^2_{i,j,t})$ is independent perception error

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- Perceived probability of default is obtained from Chebyshev's bound as

$$\mathbb{P}(z_{i,j,t} > \epsilon) \leq \frac{\sigma^2 + \tilde{\sigma}^2_{i,j,t}}{\sigma^2 + \tilde{\sigma}^2_{i,j,t} + \epsilon^2} =: P_{i,j,t}$$

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- Focus on evolution of log perception error variance (credit risk uncertainty)

$$\log \tilde{\sigma}^2_{i,j,t+1} = \alpha_\sigma + \gamma_\sigma \log \tilde{\sigma}^2_{i,j,t} + \beta_\sigma m_{i,j,t} + u_{i,j,t}, \quad u_{i,j,t} \sim \mathcal{N}(0, \sigma^2_u)$$

  where $m_{i,j,t} \in \mathbb{R}^+_0$ are monitoring expenditures

Link Formation, Interest Rates and Loan Volumes

- $B_{i,j,t} \sim \mathrm{Bernoulli}(\lambda_{i,j,t})$ indiactes link between bank i and j at time t with

$$\lambda_{i,j,t} = \frac{1}{1 + \exp(-\beta_\lambda(s_{i,j,t} - \alpha_\lambda))}$$

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- Upon contact Nash bargaining about rates, Afonso & Lagos (2012); lender surplus over deposit facility: $(1 - P_{i,j,t})r_{i,j,t} - P_{i,j,t} - \underline{r}_t$, borrower surplus over lending facility: $\overline{r}_t - r_{i,j,t}$. Solution:

$$r_{i,j,t} = \theta r + (1-\theta)\frac{P_{i,j,t}}{1 - P_{i,j,t}}$$

  where θ is bargaining power of lender, with $\overline{r}_t = r > \underline{r}_t = 0$

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- Upon successful bargaining, $r_{i,j,t} \in [0, r]$, the loan volume is exogenously given by

$$\zeta_{i,j,t} = \min\{\zeta_{i,t}, -\zeta_{j,t}\}\mathbb{I}(\zeta_{i,t} \geq 0)\mathbb{I}(\zeta_{j,t} \leq 0),$$

  where $\zeta_{i,t}$ and $\zeta_{j,t}$ are liquidity shocks specific to each transaction

Dynamic Optimization Problem

- Dynamic optimization problem of each bank i:

$$\max_{\{m_{i,j,t}, s_{i,j,t}\}} \mathbb{E}_t \sum_{s=t}^{\infty} \left(\frac{1}{1+r}\right)^{s-t} \left(\sum_{j=1}^{N} \bar{R}_{i,j,t} y_{i,j,t} + (r - r_{j,i,t}) y_{j,i,t} - m_{i,j,t} - s_{i,j,t}\right)$$

s.t. constraints; where $\bar{R}_{i,j,t} = (1 - P_{i,j,t}) r_{i,j,t} - P_{i,j,t}$, no default occurs!

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- Optimal linearized policy rules for monitoring

$$m_{i,j,t} = a + b\tilde{\sigma}^2_{i,j,t} + c\mathbb{E}_t\tilde{\sigma}^2_{i,j,t+1} + d\mathbb{E}_t\lambda_{i,j,t+1} + e\mathbb{E}_t y_{i,j,t+1}$$

$\rightarrow$ depends on current uncertainty and expected future uncertainty, loan volume and link probability

- Non-linear policy function for search

$$s_{i,j,t} = f(\mathbb{E}_t(r - r_{j,i,t}) y_{j,i,t}) \qquad f' \geq 0$$

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- Banks have adaptive expectations and compute expectations $\mathbb{E}_t \hat{x}_{i,j,t+1}$ as EWMA

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Data

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- Observed variables are $l_{i,j,t}$ (link/loan indicator), $y_{i,j,t}$ (volumes) and $r_{i,j,t}$ (spreads), for loans between $N = 50$ most active Dutch banks at daily frequency from 01-02-2008 to 30-04-2011, $T = 810$, volumes and spreads only for granted loans; three $NxNxT$ arrays (with missings)

Indirect Inference Estimator

- Idea: characterize data X by vector of auxiliary statistics β in a way that identifies structural parameters θ, then simulate $s = 1, ..., S$ different datasets X_s and choose $\hat{\theta}$ as

$$\hat{\theta} := \underset{\theta \in \Theta}{\operatorname{argmin}} \|\hat{\beta}(X) - \frac{1}{S} \sum_{s=1}^{S} \hat{\beta}(X_s(\theta))\|.$$

- $\hat{\theta}$ is consistent and asymptotically normally distributed estimator, see Gourieroux et al. (1993)
- We use quadratic form with diagonal weight matrix related to identity, $S = 24$ simulated networks with each $T^* = 3000$, and restrict parameter space Θ to ensure stability of reduced form
- Network statistics (e.g. density, reciprocity, stability, degree distribution, RL measures) and moments of volumes and spreads as auxiliary statistic, see Blasques and Bräuning (2014)

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Comparison of Auxiliary Statistics

Auxiliary statistic	Observed $\hat{\boldsymbol{\beta}}_T$	Simulated $\tilde{\boldsymbol{\beta}}_{TS}(\hat{\boldsymbol{\theta}}_T)$
Density (mean)	0.021	0.020
Reciprocity (mean)	0.082	0.060
Stability (mean)	0.982	0.978
Avg clustering (mean)	0.031	0.035
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Corr($l_{i,j,t}, \#I^{rw}_{i,j,t-1}$) (mean)	0.644	0.586
Corr($r_{i,j,t}, \#I^{rw}_{i,j,t-1}$) (mean)	-0.072	-0.123
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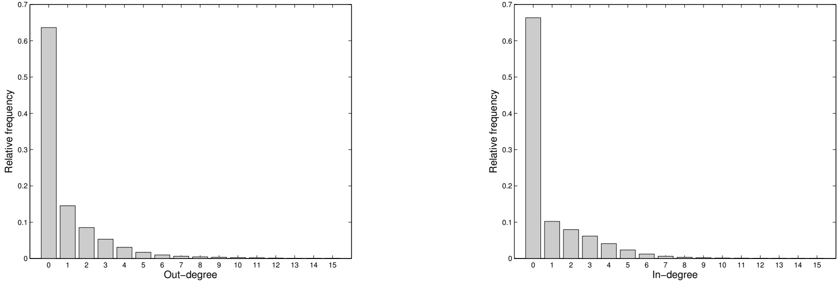
Avg log volume (mean)	4.117	4.137
Std log volume (mean)	1.690	1.136
Avg spread (mean)	0.286	1.075
Std spread (mean)	0.107	0.112

Simulated Degree Distributions



(a) Out-degree distribution (b) In-degree distribution

Auxiliary statistic	Observed $\hat{\beta}_T$	Simulated $\tilde{\beta}_{TS}(\hat{\theta}_T)$
Avg degree (mean)	1.038	0.991
Std outdegree (mean)	1.841	1.753
Skew outdegree (mean)	2.882	2.451
Std indegree (mean)	1.600	1.687
Skew indegree (mean)	2.403	2.076

Heterogeneous Liquidity Shock Distributions

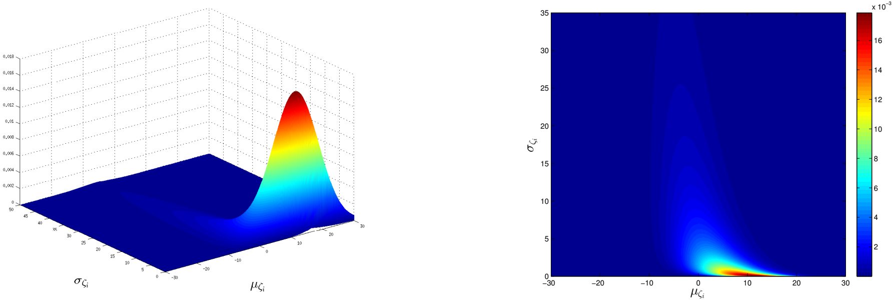


Figure : Joint distribution of mean and standard deviation parameter

$$\zeta_{i,t} \sim \mathcal{N}(\mu_{\zeta_i}, \sigma^2_{\zeta_i}) \quad \text{where} \quad \begin{pmatrix} \mu_{\zeta_i} \\ \log \sigma_{\zeta_i} \end{pmatrix} \sim \mathcal{MN} \begin{pmatrix} \sigma^2_{\mu} & \rho\sigma_{\sigma}\sigma_{\mu} \\ \rho\sigma_{\sigma}\sigma_{\mu} & \sigma^2_{\sigma} \end{pmatrix}$$

Bank Heterogeneity and Trading Relationships

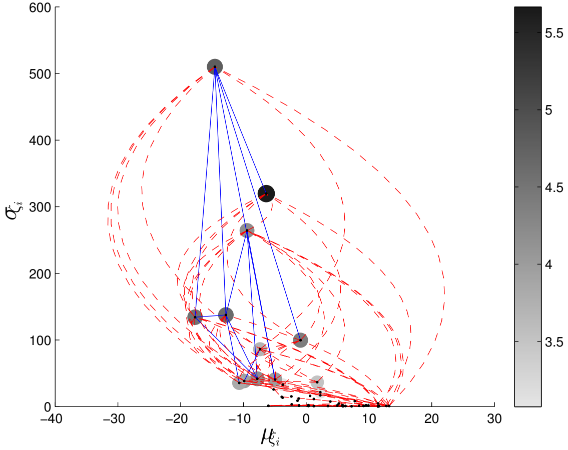


Figure : Five days of simulated interbank trading. Bank i's position in x-y plane given by parameters of its liquidity shock distribution $(\mu_{\zeta_i}, \sigma_{\zeta_i})$. Node size scaled and shaded proportional to average loan volume per bank. Directed links are plotted as curved dashed lines (red) with the curvature bending counterclockwise moving away from a node. Solid blue lines represent reciprocal links.

Comparative Statics of Network Measures

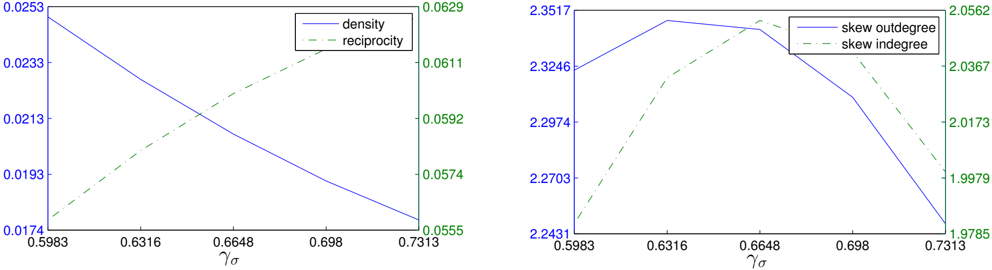
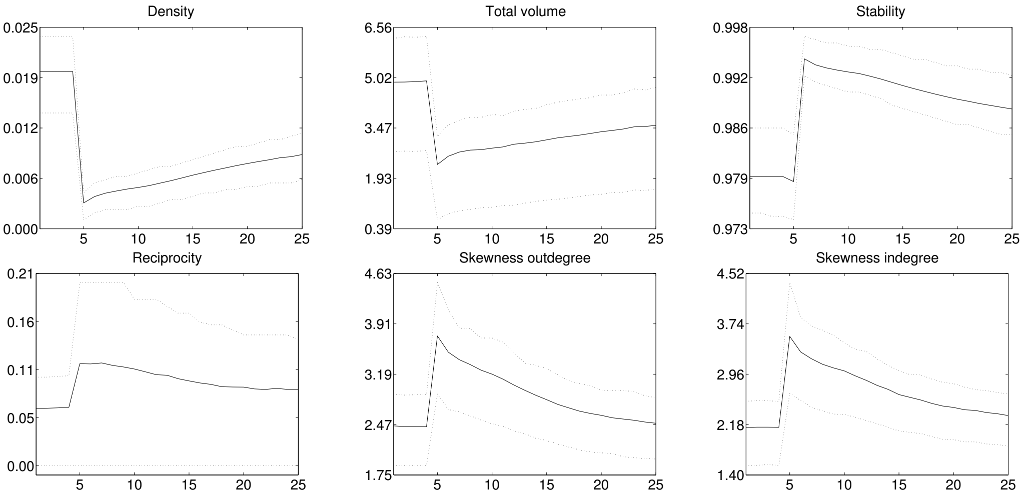


Figure : Simulated network responses to changes in persistence of credit risk uncertainty

Dynamic Network Responses to Credit Risk Uncertainty Shock



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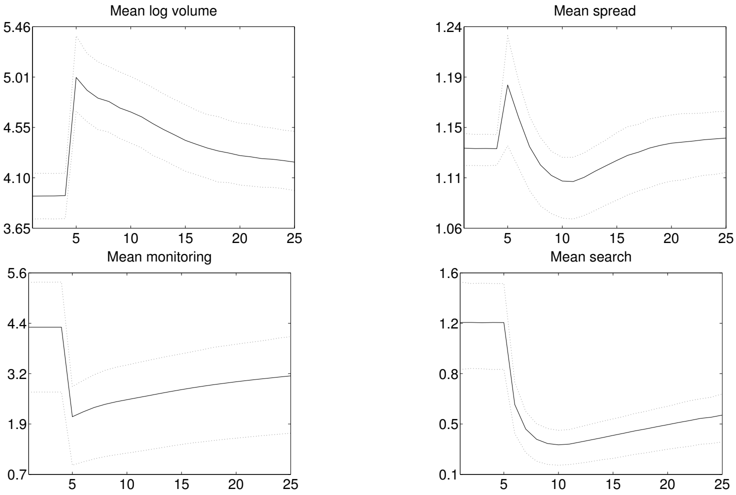
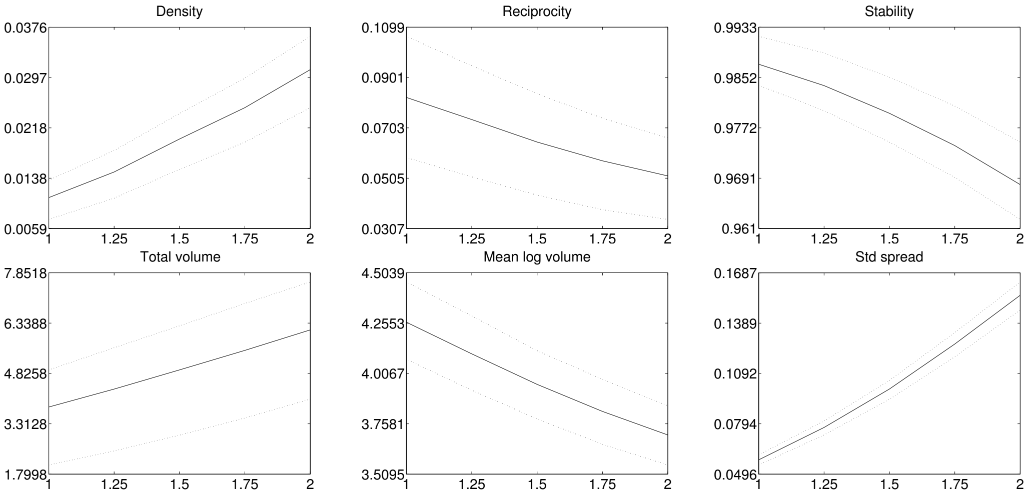
Responses of Credit Conditions, Monitoring and Search



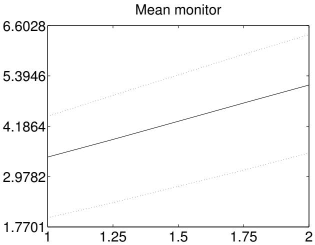
Monetary Policy Analysis

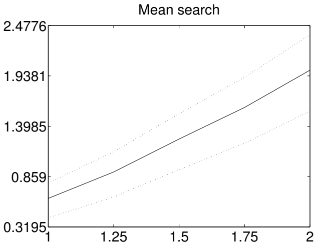
- What's the role of monetary policy on interbank network structure ?
- Focus on width of interest rate corridor as key parameter

Changes in Central Bank Interest Rate Corridor



Multiplier Effect of Monitoring





- Changes in Lending Network are driven by two effects
- *Direct effect* on interbank lending activity by altering outside options
- *Indirect multiplier effect* through changes in monitoring and search efforts

Conclusion

- We introduce and estimate structural interbank network model where banks monitor and search counterparties for bilateral bargaining
- Estimated model matches well sparse core-periphery structure of Dutch market and existence of relationship lending
- Dynamic analysis reveals importance of monitoring and search as driver behind prolonged market downturn after shock to uncertainty
- Changes in discount window lead to direct effect on interbank lending and indirect multiplier effect through altered monitoring and search efforts

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