Do interbank markets price systemic risk?

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Why should we care about prices on interbank markets?

Acemoglu et al. (2015) show that in their model of an interbank market:

- **Pricing of *immediate* counterparty risk is sufficient** for a socially optimal outcome in the absence of financial contagion effects.
- **Social efficiency does not hold in the presence of contagion effects** unless banks include these effects in their pricing (through contract covenants, in their model).

$\Rightarrow$ Failure to price contagion effects would imply a negative externality

Acemoglu, D., Ozdaglar, A. E. and Tahbaz-Salehi, A. (2015). Systemic risk in endogenous financial networks. Columbia Business School Research Paper No. 15-17.

Do banks price contagion effects?

Outline for the talk:

1. **Contagion model**
   Computing immediate counterparty risk as well as various forms of higher-order contagion effects.
2. **Pricing model**
   Strategic price formation in the absence or presence of contagion effects.
3. **Estimation**
   Structural estimation of the pricing model with different types of contagion effects.
4. **Results**

Quantification of contagion effects

We follow a standard approach in the systemic risk literature for quantifying contagion losses (see e.g. Upper 2011):

- We start with the observed network structure between and capitalization of n banks
- Each bank is set to default idiosyncratically and losses for the other $n-1$ banks are computed
- Result: $C \in \mathbb{R}_+^{n \times n}$ matrix of bilaterally caused losses

Upper, C. (2011). Simulation methods to assess the danger of contagion in interbank markets. Journal of Financial Stability, 7(3), 111-125.

From counterparty risk to higher-order contagion effects

We use a consistent framework of contagion effects of increasing complexity (Siebenbrunner et al. 2017):

First-Round losses: $C^{\text{First-Round}}$
Only losses to direct creditors, i.e. counterparty risk, are considered.

n^th-round losses: $C^{\text{n}^{\text{th}}\text{-round}} \geq C^{\text{First-Round}}$
Further losses due to default cascades (Eisenberg and Noe, 2001).

Fire Sales: $C^{\text{Fire Sales}} \geq C^{\text{n}^{\text{th}}\text{-round}}$
Asset price reductions due to liquidations.

Mark-to-Market effects: $C^{\text{MtM}} \geq C^{\text{Fire Sales}}$
Asset price reductions are recognized by all banks in the system.

Eisenberg, L. and Noe, T. H. (2001). Risk in Financial Systems. Management Science, 47(2), 236-249.

Siebenbrunner, C., Sigmund, M., and Kerbl, S. (2017). Can Bank-Specific Variables Predict Contagion Effects? Quantitative Finance, 17(12), 1805–1832.

Our pricing model is inspired by the literature on industrial organization of banking

Standard models such as Ho and Saunders (1981) extended to account for:

1. Banks are not just intermediaries of loanable funds
2. Banks do not only close funding gaps on the interbank market
3. Lending and deposit rates for interbank funds differ
4. There is no single rate for either interbank loans or deposits

Ho, T. S. Y., and Saunders, A. (1981). The determinants of bank interest margins: theory and empirical evidence. Journal of Financial and Quantitative Analysis, XVI(4).

Formal model

Banks solve the optimization problem (extension of Siebenbrunner and Sigmund, 2017):

$$\max \Pi = p_L^i * (q_L^i - \sum_{\{j \neq i\}} PD_j C_{ji}) - p_D^i * q_D^i \tag{1}$$

subject to a balance sheet constraint.

p_L^i, q_L^i	Prices and quantities of interbank loans
p_D^i, q_D^i	Prices and quantities of interbank deposits
C_{ji}	Losses for i following default of j
	$C \in \{\mathbf{0}^{N \times N}, C^{\text{First-Round}}, C^{\text{n}^{\text{th}}\text{-round}}, C^{\text{Fire Sales}}, C^{\text{MtM}}\}$

Banks play a Bertrand game with horizontally differentiated demand functions for interbank loans and deposits.

Siebenbrunner C. and Sigmund, M. (2017). Determinants of interbank market rates: theory and empirical evidence. SSRN Working Paper

Inclusion of contagion effects in the pricing model

Note that we specified five different models using different loss variables:

- $C = C^{\text{First-Round}}$ is the model where only immediate counterparty risk is priced, corresponding to standard risk-adjusted return optimization.
- $C \in \{C^{\text{n}^{\text{th}}\text{-round}}, C^{\text{Fire Sales}}, C^{\text{MtM}}\}$ are models where different types of higher-order contagion effects are priced.
- $C = \mathbf{0}^{N\times N}$ is a benchmark model where no losses are priced.

Our aim in the estimations is to decide which of these models best correspond to the data.

Empirical implementation of the model

The Nash equilibrium of the pricing model takes the form of a simultaneous equation system:

$$\begin{pmatrix} p_L \\ p_D \end{pmatrix} = f \begin{pmatrix} p_D \\ p_L \end{pmatrix} \tag{2}$$

Simultaneity is confirmed by a series of statistical tests.

We estimate this system using 2SLS and 3SLS and the following data set:

- Austrian supervisory and credit registry information, including bank's internal PDs
- Quarterly observations from 2008Q1 to 2016Q1 ($T = 32$)
- Panel of $N = 716$ banks

Identification is based on different demand drivers for loans and deposits

Variable description	Deposit Rate	Loan Rate
Loan rate	✓	
Deposit rate		✓
Total assets	✓	✓
Funding share from the same sector (relationship proxy)	✓	
Lending share to the same sector (relationship proxy)		✓
EURIBOR (instrument for aggregate borrowing rate)	✓	
10y government bond yield		✓
Weighted average of bilaterally assigned deposit PDs	✓	
Weighted average PD of interbank loans		✓
Average loan risk weight		✓
Funding gap	✓	✓
Average collateral ratio of interbank deposits	✓	
Average collateral ratio of interbank loans		✓
Losses received		✓

Table: Mapping of variables to equations

Results: Loan rate equation

ID	Benchmark	First-Round	n^{th}-round	Fire Sales	MtM
DR	1.1972 ***	1.1954 ***	1.1952 ***	1.1951 ***	1.1951 ***
TA	0.2302 ***	0.2453 ***	0.249 ***	0.2459 ***	0.2451 ***
FG	-0.0044 ***	-0.0046 ***	-0.0046 ***	-0.0046 ***	-0.0046 ***
RW	0.0097 ***	0.0096 ***	0.0096 ***	0.0096 ***	0.0096 ***
LS	-0.0014 ***	-0.0013 **	-0.0012 **	-0.0012 **	-0.0013 **
LTI	0.2246 ***	0.2269 ***	0.2276 ***	0.2272 ***	0.2271 ***
PD	2.3855 ***	3.7812 ***	3.8058 ***	3.7474 ***	3.751 ***
COL	-0.2273 **	-0.2185 **	-0.1996 **	-0.2061 **	-0.2193 **
FR		-0.0121 ***	29.4912 *	3.4036	-0.0147
NR			-29.5015 *		
FS				-3.415	
MtM					0.0027
Hansen	1.4698	1.6947	8.7915	8.9441	7.7048
McElroy R^2	0.7958	0.7936	0.7926	0.7934	0.7937

Results: Deposit rate equation

ID	Benchmark	First-Round	n^{th}-round	Fire Sales	MtM
LR	-0.066 ***	-0.0701 ***	-0.073 ***	-0.0709 ***	-0.07 ***
TA	-0.114 ***	-0.1164 ***	-0.1162 ***	-0.1139 ***	-0.1157 ***
FG	-0.001 *	-0.001 *	-0.0011 *	-0.001 *	-0.001 *
FS	0.0019 ***	0.0019 ***	0.0018 ***	0.0019 ***	0.0019 ***
STI	0.4755 ***	0.4784 ***	0.4804 ***	0.4791 ***	0.4785 ***
PD	-0.3259	-0.3643	-1.1007 ***	-0.805 *	-0.4575
COL	-0.1273 ***	-0.1276 ***	-0.1206 ***	-0.1223 ***	-0.1287 ***
FR		2e-04	0.0377 ***	0.019 **	0.0011
NR			-0.0263 ***		
FS				-0.0127 **	
MtM					0
Hansen	1.4698	1.6947	8.7915	8.9441	7.7048
McElroy R^2	0.7958	0.7936	0.7926	0.7934	0.7937

Results highlights: coefficients of loss variables

	Benchmark	First-Round	n^{th}-round	Fire Sales	MtM
Coefficients in loan rate equation					
First-Round		-0.0121 ***	29.4912 *	3.4036	-0.0147
n^{th}-round			-29.5015 *		
Fire Sales				-3.415	
MtM					0.0027
Coefficients in deposit rate equation					
First-Round		2e-04	0.0377 ***	0.019 **	0.0011
n^{th}-round			-0.0263 ***		
Fire Sales				-0.0127 **	
MtM					0
Hansen	1.4698	1.6947	8.7915	8.9441	7.7048
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Discussion of results

We compare models by statistical criteria as well as economic interpretation of the coefficients. We note

- Explanatory power (as measured by McElroy R^2) is largely the same for all models
- The Hansen overidentification statistic is better for the benchmark and First-Round models, but not significantly
- Coefficients of First-round losses are largely, but not always, significant and positive
- Coefficients of higher-order losses are negative, if significant

Are contagion effects priced in interbank markets?

Observations:

- Coefficients show that higher-order losses are priced wrongly, if at all.
- In statistical terms, not many differences between the models, including the benchmark.

By Ockham's razor principle, we would give preference to the benchmark model. We conclude:

- No evidence that losses are priced correctly.
- If anything, higher contagiousness means lower prices!

Conclusion

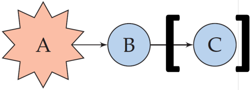
- Acemoglu et al. (2015) showed that failure to price contagion losses on interbank markets creates a negative externality.
- We assess this question empirically, using Austrian data.
- We find that contagion losses are not priced appropriately.

Appendix

First-round effects

- Contagion losses are only computed for one node after a defaulted node
- No network effects are considered
- Reason for including: should be the type of contagion effects that can be best proxied using bank-specific data

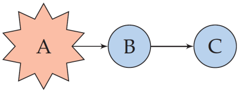
Schema of first-round effects



n^{th}-round effects

- Contagion losses are computed for all chains emanating from a defaulted node
- Entire network is considered
- Based on the Eisenberg/Noe model:
  - Every bank repays the minimum of its total obligations and its remaining assets
  - Each bank's assets are a function of its debtor banks' balance sheets
  - Repayments are split equally among creditors (no seniority)

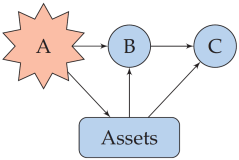
Schema of n^{th}-round effects



Asset fire sales

- Eisenberg/Noe model assumes that all remaining assets can be liquidated at book value
- Fire sales model accounts for liquidation losses - increases losses for creditors
- Common market for banking assets: the more banks are in default at the same time, the higher liquidation losses are

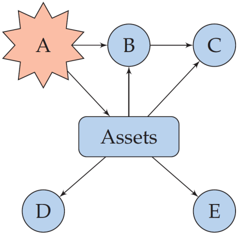
Schema of asset fire sales effects



Mark-to-market effects

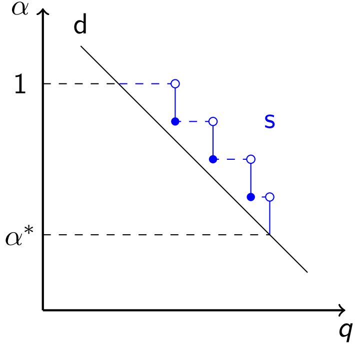
- Asset fire sales losses only affect creditors of defaulted banks through increased haircuts on interbank exposures
- Under mark-to-market accounting, lower market prices for banking assets have to be recognized by all banks in the system
- Setup roughly equivalent to Cifuentes/Ferrucci/Shin model

Schema of asset fire sales effects



Asset fire sales model

- Used for both asset fire sales and mark-to-market effects
- Price α starts at 1 (100% of original asset value)
- Each time a new bank enters into default, its entire assets are sold into the market
- Iteration stops when supply of banking assets first intersects exogenous demand function



Calibration of demand function for interbank assets

- Linear demand function assumed - basic intuition:
  - When no fire sales happen prices are fixed at 1
  - When there are no more buyers, price should in theory be 0

$$d^{-1}(\mathit{SoldAssets}) = 1 - \kappa \frac{\mathit{SoldAssets}}{\mathit{TotalAssets}} \tag{3}$$

- However, there are external buyers not represented in the system being modeled
- Slope parameter calibrated using free leverage of external buyers:

$$\kappa = \frac{\sum_{i=1}^{N-1} \mathit{Assets}_i}{\sum_{i \in \text{external Buyers}} \max\left(\frac{\mathit{Capital}_i - \mathit{Assets}_i * \theta}{\theta}, 0\right)} \tag{4}$$

- In our application: Austrian banking system, external buyers are major European banks (significant institutions under SSM supervision), giving $\kappa \approx 0.5$
- Exact leverage targets used are confidential