Estimating Network Contagion with Limited Data

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Motivation

Assessing the systemic risk an institution poses to the system has become a central part in regulating its capital requirements (e.g. the buffer for global or domestic systemically important institutions) but also in determining the amount of supervisory attention an institution receives.

As with conventional risk types, systemic risks need to be quantified. Currently regulators propose a range of bank-specific indicators that measure size and interconnectedness (BIS, EBA, FED) to proxy systemic risk. In this study we explore how well the proposed indicators or an enlarged data set of bank-specific indicators can quantify outward and inward contagion.

Data

Name	Description	Normalized by total assets	OSI
Log total assets	Logarithm of total assets	No	Yes
Nonbank deposits	Deposits taken from domestic and foreign nonbanks (i.e. customers), all currencies	yes	Yes
Loans to nonbanks	Loans to foreign and domestic nonbanks	Yes	Yes
OTC derivatives	Notional value of OTC derivatives	Yes	Yes
Loans to foreign customers	Loans to foreign domiciled nonbanks and banks	Yes	Yes
Deposits from foreign customers	Deposits from foreign domiciled nonbanks and banks	Yes	Yes
Bank deposits	Deposits taken from domestic and foreign banks, all currencies	Yes	Yes
Bank loans	Loans to domestic and foreign banks, all currencies	Yes	Yes
Securitized debt	Liabilities in the form of securitized debt obligations and transferable certificates	Yes	Yes
Net interest margin	Net interest income over total assets	by definition	No
Interest rate nonbank loans	Average interest rate on nonbank loans	No	No
Interest rate bank loans	Average interest rate on bank loans	No	No
Interest rate nonbank deposits	Average interest rate on nonbank deposits	No	No
Interest rate bank deposits	Average interest rate on bank deposits	No	No
LLP ratio	Specific loan loss provisions over gross exposure (loans to domestic and foreign nonbanks, all currencies), smoothed	No	No
Tier 1 capital ratio	Eligible tier 1 capital over RWA	by definition	No
Tier 1 capital ratio credit risk	Eligible tier 1 capital over RWA for credit risk	by definition	No
Leverage ratio	Eligible tier 1 capital over total assets	by definition	
RWA	Total risk-weighted assets	Yes	No
RWA credit risk	risk-weighted assets (credit risk only)	Yes	No
Net fee income	Net fee and commission income (smoothed)	Yes	Yes
Interest-bearing securities	Exchange-traded interest-bearing securities (held as assets) issued by domestic and foreign banks and nonbanks, all currencies	Yes	No
Staff expenses	Staff expenses	Yes	No
Other operating expenses	Operating expenses other than staff expenses	Yes	No
N-Ingoing Links	Number of bank deposits	No	No
N-Outgoing Links	Number of bank loans	No	No

Conclusion

- Our first results suggest that first round contagion can be well approximated by the indicators proposed by international regulators.
- Extending the data coverage to a larger sample of bank-specific variables or to seems not to improve the overall fit substantially.
- However, when replacing the dependent variable by the total losses after taking second and higher order domino-effects into account both the simple set of indicators as well as the extended sample show surprisingly low predictive power.
- A lesson is that from the perspective of financial stability and systemic risk it is not sufficient to look at individual bank-level data but to invest in obtaining and analyzing the more data-demanding network structures.

Balance Sheet Model

Value of interbank claims depends on payments vector p:

Interbank assets $(\Pi' p)_i$	Equity $e_i + (\Pi' p)_i - \bar{p}_i$
Other assets e_i	Liabilities $\bar{p}_i$

Figure 1: Balance sheet of firm i

Stress scenarios: general as well as idiosyncratic shocks are captured in a shock matrix Γ.

Clearing payment vector $p^{*,1}(\alpha, \Gamma)$ (fixed point):

$$\Phi_1(p)_i = \begin{cases} \bar{p}_i & \text{if } \bar{p}_i \leq e_i\Gamma_{ii} + (\Pi' p)_i \\ \alpha e_i \Gamma_{ii} + (\Pi' p)_i & \text{otherwise} \end{cases}$$

- Solvent banks repay their obligations $\bar{p}_i$ in full
- Defaulted banks: liquidation losses $(1-\alpha)$ on non-interbank assets
- Defaulted banks repay the recovery value of non-interbank $\alpha e_i \Gamma_{ii}$ plus equilibrium value of interbank assets $(\Pi' \bar{p})_i$

Asset Fire Sales Model

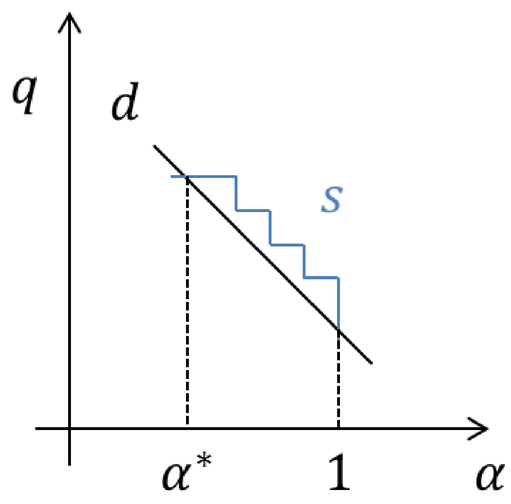

Figure 2: Tâtonnement process

Dynamics for mark-to-market effects analogous, but all banks have to recognize depreciation non-interbank assets

Supply of firesold assets:

$$s(p, \Gamma) = \sum_{\{i \in \mathcal{N} \,:\, \Gamma_{ii} e_i + (\Pi' p)_i < \bar{p}_i\}} e_i$$

Inverse demand function:

$$d^{-1}(p, \Gamma) = \alpha(p, \Gamma) = 1 - \kappa * \frac{s}{\sum_{i=1}^{n} e_i}$$

Equilibrium price $\alpha^{*,1}(\Gamma)$ fixed point of the map:

$$\Theta_1(\alpha) = d^{-1}(p^{*,1}(\alpha, \Gamma), \Gamma)$$

Where:

- $p^{*,1}(\alpha, \Gamma) = \Phi_1(p^{*,1}(\alpha, \Gamma))$
- $\kappa \in [0, 1]$ is the share of banks in the system among all buyers

Econometric Approach

We estimate the losses caused by the default of bank i at time t, $y_{i,t}$ as a function of explanatory variables $X_{i,t}$ in a fixed effects panel approach with $N = 1,011$ banks observed for $T = 28$ time periods.

$$y_{i,t} = \alpha + \beta' X_{i,t} + u_{i(t)} + e_{i,t}, \quad i = 1, \cdots, N, \quad t = 1, \cdots, T.$$

The dependent variables are constructed by considering the total losses caused by a default of one bank: $\sum_{i=1}^{N} p^*(\alpha, \Gamma)_i - \bar{p}_i$, where $p^*(\alpha, \Gamma)$ is computed for different specifications using the models described above.

Results

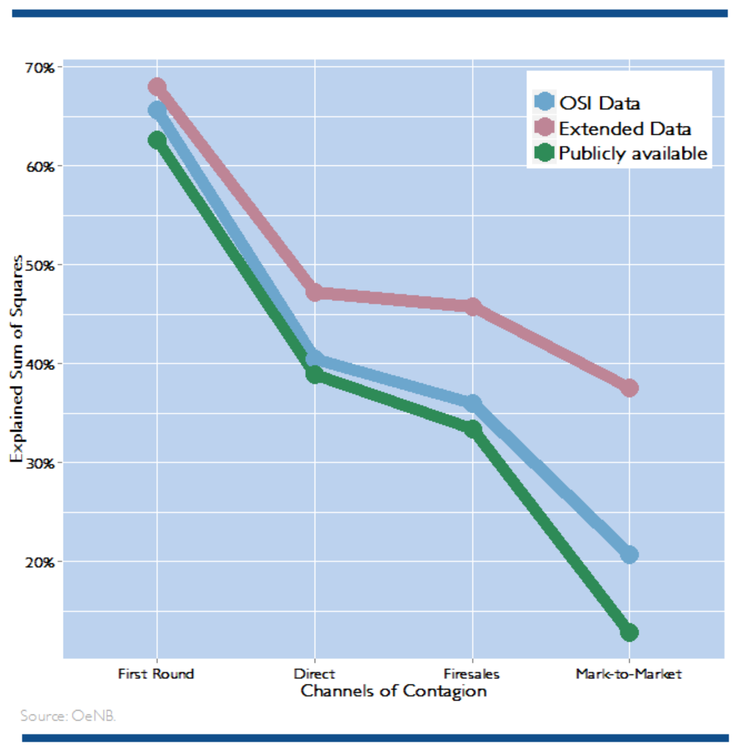

Figure 3: Explained Sum of Squares

Publicly available information **performs well for estimating first-round contagion losses**. Unsurprisingly, The variable "interbank liabilities" accounts for nearly 100% of the explanatory power.

However, **explanatory powers drops when network effects** from *n-th* round contagion effects or asset fire sale effects **are considered**. For equilibrium losses under mark-to-market accounting, the explanatory value drops further, close to 0.

Adding simple, bank-level **network metrics** and other non-disclosed information to the set of explanatory variables **improves the fit substantially**, especially for mark-to-market effects. However, the model performance remains weak, especially when considering the fact that figure 3 displays an in-sample fit.

Interestingly, even key explanatory variables like "interbank liabilities" become marginally important when considering network effects, while other variables describing general network characteristics, e.g. number of outgoing links, gain in importance.