Quantifying the importance of contagion channels as sources of systemic risk

Christoph Siebenbrunner [1,2]
christoph.siebenbrunner@oenb.at

[1]Institute of Management Science
Vienna University of Technology

[2]Department of Financial Stability, Banking Supervision and Statistics
Oesterreichische Nationalbank

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Previous work is inconclusive as regards the importance of contagion effects

- Direct contagion: bank A has lent to bank B and faces a loss if B defaults
- Several studies suggest that the effect has limited impact: Furfine 2003, Elsinger, Lehar, and Summer 2006, Degryse and Nguyen 2007, Nier et al. 2008, Georg 2013, Glasserman and Young 2014
- Recent work suggests that direct contagion is relevant if other effects (overlapping portfolios) are included: Caccioli et al. 2015

The aim of this work is to separate the effects of different contagion channels and to quantify their importance.

I develop a framework for quantifying and separating the effects of different contagion channels

I study the effects of the following contagion channels:

- Direct contagion
- Asset fire sales
- Mark-to-market accounting

While accounting for:

- General and idiosyncratic shocks
- Correlated exposures (overlapping portfolios)

Computation of contagion effects

Model of Eisenberg and Noe 2001:

- Computes equilibrium losses under contagion
- Solvent banks repay their obligations in full
- Defaulted banks repay the value of their non-interbank assets plus the equilibrium payments they receive on interbank assets

Model Extension (Rogers and Veraart 2013):

- Introduces liquidation costs (haircuts on liquidated assets)
- Recovery value α for non-interbank and β for interbank assets
- I show that $\beta = 1$ has to hold to avoid inconsistencies (proof in Annex)

Accounting for general, idiosyncratic and correlated shocks

Model extension:

- Shock matrix $\Gamma(\gamma)$ depending on general shock level γ
- Results shown in presentation: assumption of perfectly correlated assets (common asset)
- Impact $\Gamma(\gamma, \rho)$ for common correlation parameter ρ in Annex

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

$$\Phi_1(p)_i = \begin{cases} \bar{p}_i & \text{if } \bar{p}_i \leq e_i \Gamma_{ii} + (\Pi' p)_i \\ \alpha e_i \Gamma_{ii} + \beta (\Pi' p)_i & \text{otherwise} \end{cases} \quad (1)$$

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

Asset fire sales, endogenous and mark-to-market effects

Asset fire sales

- Sales below book value induce liquidation costs
- Liquidation costs amplify losses

Endogeneity under correlated assets

- New defaults increase supply of firesold assets
- Drives down prices, increasing liquidation losses
- Vicious circle: defaults $\uparrow$ supply $\uparrow$ prices $\downarrow$ losses $\uparrow$ defaults $\uparrow$

Mark-to-market effects from overlapping portfolios

- All banks recognise liquidation losses on common assets
- Further losses, regardless of interbank exposures

Computing equilibrium prices under asset fire sales

- Supply of firesold assets

$$s(p,\Gamma) = \sum_{\{i\in\mathcal{N}:\ \Gamma_{ii}e_i+(\Pi' p)_i<\bar{p}_i\}} e_i \tag{2}$$

- Inverse demand function:

$$d^{-1}(p,\Gamma) = \alpha(p,\Gamma) = 1-\kappa * \frac{s(p,\Gamma)}{\sum_{i=1}^{n} e_i} \tag{3}$$

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

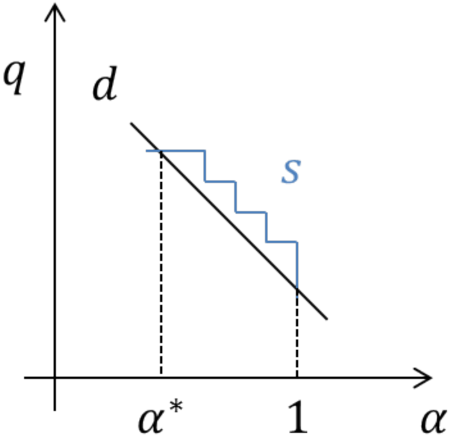
$$\Theta_1(\alpha) = d^{-1}(p^{*,1}(\alpha,\beta,\Gamma),\Gamma) \tag{4}$$

where $p^{*,1}(\alpha,\beta,\Gamma) = \Phi_1(p^{*,1}(\alpha,\beta,\Gamma))$

- $\kappa \in [0,1]$ is the share of banks in the system among all buyers
- When all banks are in default, price $\alpha = 1-\kappa$ (here $\kappa = 1$)
- Dynamics for mark-to-market effects analogous (in Annex)

Equilibrium adjustment under asset fire sales

Dynamics of the tâtonnement process:



Impact assessment I (shock impact)

Impact measured by Jaccard-Index (share of defaulted banks):

$$\eta(e,p) = \frac{|\{i \in \mathcal{N} : e_i + (\Pi' p)_i < \bar{p}_i\}|}{|\mathcal{N}|} \tag{5}$$

Measured for different combinations of contagion channels:

i General shock only (benchmark)

ii Shock + direct contagion

iii Shock + asset fire sales

iv Shock + direct contagion + asset fire sales

v Shock + direct contagion + asset fire sales + mark-to-market

Framework allows for direct computation, e.g. for (iv):

$$\eta(\alpha^{*,1}(\Gamma(\gamma))\Gamma(\gamma)e, p^{*,1}(\alpha^{*,1}(\Gamma(\gamma)), 1, \Gamma(\gamma))), \forall \gamma \in [0,1] \tag{6}$$

Impact assessment II (impact of contagion channel)

Impact of contagion channel for given shock level: shock delta when channel is activated:

$$\zeta(\gamma) = \eta(\cdot_{11}, \cdot_{12}) - \eta(\cdot_{21}, \cdot_{22}) \tag{7}$$

Aggregated across shock levels:

- Maximum impact measure:

$$\zeta^* = \max_{0 \leq \gamma \leq 1} \zeta(\gamma) \tag{8}$$

- Average impact measure:

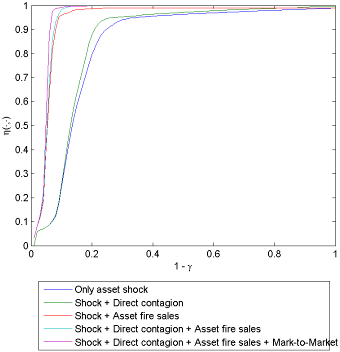
$$\bar{\zeta} = \int_0^1 \zeta(\gamma)\, \mathrm{d}\gamma \tag{9}$$

Data used

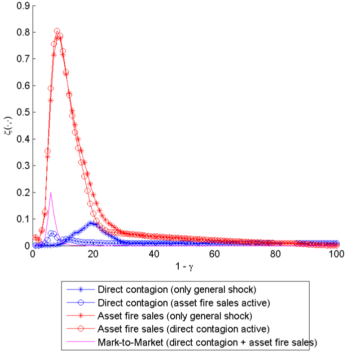
- Data on complete network of interbank loans for Austrian banks from Central Credit Registry
- Quarterly data from 2008 Q1 to 2014 Q4
- Unbalanced panel, average number of banks: 814
- Data on bank balance sheets and capitalisation from regulatory reporting system
- Non-Time series results are averaged over the time horizon

Results I - Asset fire sales have the highest impact of all contagion channels

Shock impact (η)

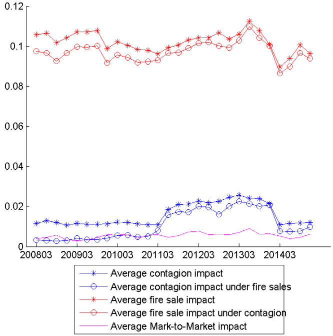


Impact of contagion channels (ζ)

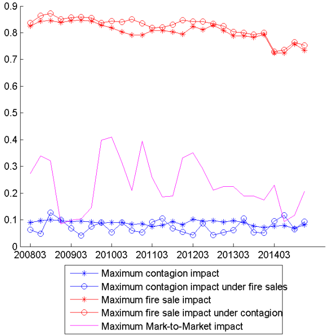


Results II - Results do not show obvious trends

Evolution of average impact ($\bar{\zeta}$)



Evolution of max. impact (ζ^*)



Results III - Discussion

Results

- Asset fire sale channel has by far the highest impact
- Impact of direct contagion channel is more platykurtic than impact of mark-to-market channel
- Maximum impact of mark-to-market by far the most volatile
- No clear trends over time for any of the measures

Policy Implications

- Asset fire sales pose a major risk to financial stability in a contagion scenario
- Quantitative easing potential mitigation measure?
- Mark-to-Market accounting can significantly increase crisis impact

Conclusion

Methodological contributions

- A common framework for assessing multiple contagion channels was developed
- Impact of a contagion channel can be measured in the presence or absence of other channels
- The framework allows accounting for general shocks and correlated exposures (overlapping portfolios)

Empirical results

- Model was evaluated using Austrian interbank data from 2008Q1 to 2014Q4
- Asset fire sales were found to be the most significant channel

Further directions

- Robustness checks - use different impact measures η
- Investigate asset fire sale channel further (discussion in Annex)

Annex

Annex I - Loss correlation framework

General framework

- Diagonal shock matrix Γ
- Γ_{ii} is the remaining value of illiquid asset holdings of bank i

Implementation with common correlation parameter

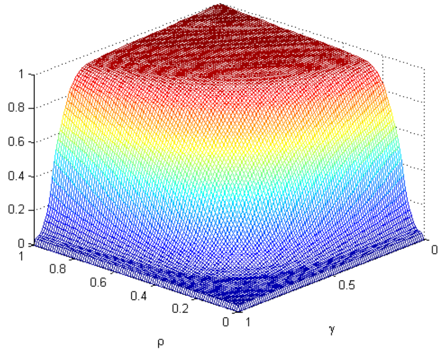
- Idiosyncratic Shock γ to non-interbank assets of bank i
- All other banks' non-interbank assets correlated with coefficient ρ
- Shock matrix for idiosyncratic shock with correlated assets:

$$\Gamma(\gamma, \rho, i)_{jk} = \begin{cases} \gamma & \text{if } j = k = i \\ 1 - (1-\gamma)\rho & \text{if } j = k \neq i \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

- For $\rho = 1$, $\Gamma(\gamma, \rho, i)_{jk}$ simplifies to $\Gamma(\gamma)$ (used in presentation)

Annex I - Loss correlation results

- Plot of impact function $\eta(\Gamma(\gamma, \rho, i)e, p^{*,1}(1, 1, \Gamma(\gamma, \rho, i)), \forall \gamma, \rho \in [0, 1]$ averaged across banks and time



Annex II - Show that β should be 1

Proposition

The value of the financial system is bounded below by 0 iff $\beta = 1$

Proof

Value of the entire system after contagion losses citeRogers2013:

$$\sum_{i=1}^{n} e_i - \sum_{\{i:\ p_i^* < \bar{p}_i\}} ((1-\alpha)e_i + (1-\beta)(\Pi' p)_i) \tag{11}$$

With $\beta < 1$ this value is negative when:

$$\sum_{i=1}^{n} e_i - \sum_{\{i:\ p_i^* < \bar{p}_i\}} (1-\alpha)e_i < \sum_{\{i:\ p_i^* < \bar{p}_i\}} (1-\beta)(\Pi' p)_i \tag{12}$$

Annex III -Mark-to-market effects

- Under mark-to-market all banks are forced to recognize liquidation losses
- Increased contagion potential
- Equilibrium recovery value $\alpha^{*,2}(\Gamma)$ under mark-to-market:

$$\Theta_2(\alpha) = d^{-1}(p^{*,2}(\alpha, \beta, \Gamma), \Gamma) \tag{13}$$

- Under a more punitive clearing payment vector $p^{*,2}(\alpha, \beta, \Gamma)$:

$$p^{*,2} = \Phi_2(p^{*,2}) \tag{14}$$

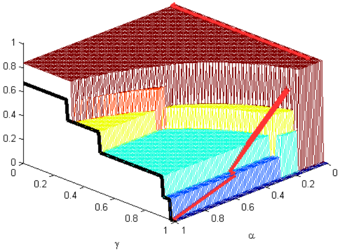
where

$$\Phi_2(p)_i = \begin{cases} \bar{p}_i & \text{if } \bar{p}_i \leq \alpha e_i \Gamma_{ii} + \beta(\Pi' p)_i \\ \alpha e_i \Gamma_{ii} + \beta(\Pi' p)_i & \text{otherwise} \end{cases} \tag{15}$$

Annex IV - Impact of market reaction function

- High importance of asset fire sale channel merits further attention
- Result partially driven by assumption about market reaction function
- Market reaction to fire sales would be a research project of its own

Possible contribution in this study: demonstrate impact of assumed market reaction function by plotting the impact across the full set $\gamma \times \alpha$ and highlight the trajectory implied by the chosen impact function (see toy example)



Annex IV - Impact of market reaction function

Impact of market reaction function can be plotted for the following specifications:

- Common shock + Asset fire sales

$$\eta(\alpha\Gamma(\gamma)e, \bar{p}), \forall\alpha, \gamma \in [0, 1] \tag{16}$$

- Common shock + Direct contagion + Asset fire sales

$$\eta(\alpha\Gamma(\gamma)e, p^{*,1}(\alpha, 1, \Gamma(\gamma))), \forall\alpha, \gamma \in [0, 1] \tag{17}$$

- Common shock + Direct contagion + Asset fire sales + Mark-to-Market

$$\eta(\alpha\Gamma(\gamma)e, p^{*,2}(\alpha, 1, \Gamma(\gamma))), \forall\alpha, \gamma \in [0, 1] \tag{18}$$