BSLoss - a comprehensive measure for interconnectedness

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The paper presents the authors personal opinions and does not necessarily reflect the views of the Deutsche Bundesbank or its staff.

Motivation

Measure the risk of contagion in the banking system

- Shock to one bank or a group of bank spreads over to other banks
- Balance sheet losses caused by deterioration of the quality of interbank credits

Measure of the systemic importance of individual banks

- Our method builds on the **DebtRank** as proposed by Battiston et al. (2012)

Objectives and research questions

Quantify negative externalities from interconnectedness

- Algorithm for contagion process:
  i. How does the credit quality of the creditor bank depend on the credit quality of the debtor bank?
- Economically meaningful measure:
  i. Forward looking view (sensitive to changes in credit risk)
  ii. Market value based approach (expressed in monetary units)

Evaluate the effectiveness of different policy actions to curb contagion

- How effectively do alternative levels of capital buffers absorb different types of shocks?

The Algorithm: Intuition

Simulate the impact of a change in the debtor bank's PD on the creditor bank's PD.

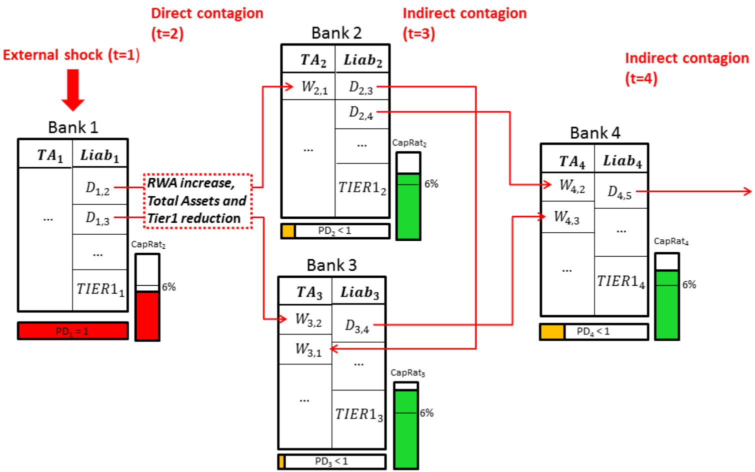
Two-step approach:

i. Debtor bank's PD has an impact on creditor bank's Tier1 capital ratio
ii. Creditor bank's Tier1 capital ratio influences its PD

Contagion process starts with an initial shock (increase of one or a group of bank's PD) which propagates via interbank credits and results in a mutual increase of creditor banks' PDs.

$\Rightarrow$ **Persistent feedback loop / multi-round process**

The Algorithm: Illustration



Methodology: Propagation mechanism (1/2)

Update of core variables

- Update of creditor banks' TAs, Tier1 capital, and RWAs in every round
- Depends on the change in the debtor banks' PDs and the volume of loans to the respective debtor banks

$$TA_{i,t} = TA_{i,t-1} - \sum_j W_{ij} \cdot LGD \cdot (PD_{t-1}(j|A) - PD_{t-2}(j|A))$$

$$Tier1_{i,t} = Tier1_{i,t-1} - \sum_j W_{ij} \cdot LGD \cdot (PD_{t-1}(j|A) - PD_{t-2}(j|A))$$

$$RWA_{i,t} = RWA_{i,t-1} + \sum_j \Delta_t RW_j \cdot W_{ij}$$

W_{ij}: credit from bank i to bank j
LGD: loss given default
$\Delta_t RW_j$: change in risk weights based on IRB function

Methodology: Propagation mechanism (2/2)

Empirical relationship between Tier1 capital ratio and PD

- Impact of banks' Tier1 capital ratio on its PDs derived from a logit-regression as in Craig, Kötter and Krüger (2014)

$$Pr(default_t) = F(\alpha + \beta_{caprat} ln(CapRat_{t-1}) + \gamma X_{t-1}),$$

$$CapRat_t = \frac{Tier1_t}{RWA_t}$$

$F(z) = e^z/(1 + e^z) \Rightarrow$ cumulative logistic distribution

X : matrix containing additional control variables (*CAMEL*)

Methodology: Algorithm (initial shock)

Introduction of the shock to the system

$t = 1$: Exogenous shock hits certain banks

$$PD_1(i|A) = PD_0(i) + \varphi \leq 1 \qquad \forall\, i \in S,$$
$$PD_1(i|A) = PD_0(i) \qquad \forall\, i \notin S.$$

A : Shock event

φ : Level of stress imposed on bank (> 0)

$PD_t(i|A)$: Conditional PD of bank i in round t

$PD_0(i)$: Unconditional PD of bank i in round $t = 0$

S : set of banks subject to the shock

Methodology: Algorithm (contagion)

Update of PD

$t = 2$, iterate

$$PD_t(i|A) = \begin{cases} 1 & \text{if } CapRat_{i,t} < CapRat_{crit} \\ & \text{or } Lev_{i,t} < Lev_{crit} \\ min\{1, PD_{t-1}(i|A) + \beta_{caprat} \cdot \phi \cdot \Delta_t ln(CapRat_i)\} & \text{else,} \end{cases}$$

$t = t + 1$, until $P_T(i|A) - P_{T-1}(i|A) < \epsilon$ with a small value $\epsilon > 0$

$$\phi = PD_{t-1}(i|A) - PD_{t-1}(i|A)^2$$

$$\Delta_t ln(CapRat_i) = ln(\frac{Tier1_{i,t}}{RWA_{i,t}}) - ln(\frac{Tier1_{i,t-1}}{RWA_{i,t-1}})$$

Unit to measure interconnectedness

Banking System Loss

In round T the algorithm stops and the banking system loss can be calculated as follows:

$$BSLoss = \sum_{i \,\in\, \text{all banks}} [TA_{i,1} - TA_{i,T}]$$

Features of BSLoss

... reflects the aggregated credit losses in the banking system initiated by the exogenous shock

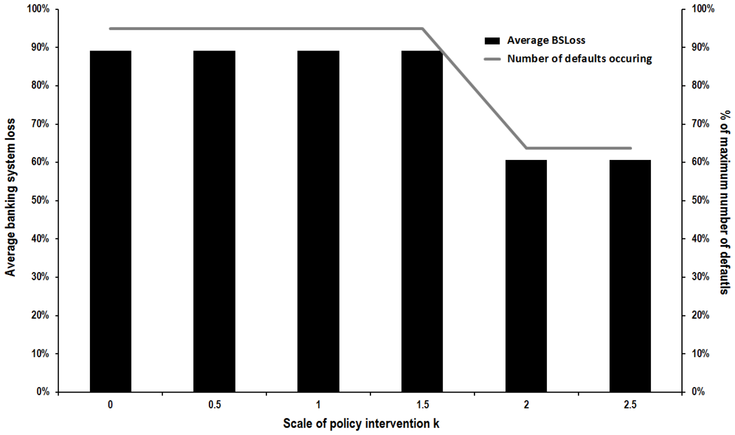
... takes into account direct contagion (from debtor to creditor bank) and indirect contagion (from debtor to creditor's [...] creditor bank)

Ranking of banks

"Too-interconnected-to-fail", direct and indirect contagion effects

	Total effect			Direct effect - Round 2 -		Indirect effect - Following rounds -	
Rank	$\frac{BSLoss_i^T}{BSLoss_1^T}$	# rounds	$\frac{defaults_i^T}{defaults_1^T}$	$\frac{BSLoss_i^{dir}}{BSLoss_i^T}$	% $defaults_i^T$	$\frac{BSLoss_i^{ind}}{BSLoss_i^T}$	% $defaults_i^T$
1	100%	16	100%	5%	3%	95%	97%
2	100%	14	100%	5%	4%	95%	96%
3	100%	14	100%	8%	4%	92%	96%
4	100%	14	100%	6%	4%	94%	96%
5	100%	10	100%	10%	5%	90%	95%
6	35%	11	70%	36%	79%	64%	21%
7	11%	10	2%	47%	46%	53%	54%
8	9%	11	2%	59%	71%	41%	29%
9	7%	9	12%	65%	98%	35%	2%
10	6%	10	1%	46%	50%	54%	50%

Average *BSLoss* for alternative capital buffers for SIFIs



Conclusion

Analytical framework that quantifies contagion risks

- Identification of systemically important banks
- Evaluation of the effectiveness of policy actions

Some ideas for extension

- Inclusion of non-bank financial institutions (eg insurers)
- Comparison between countries' financial systems / dynamic analyses
- Unconditional BSLoss; weighted by rating downgrade probabilities of the shocked banks

References

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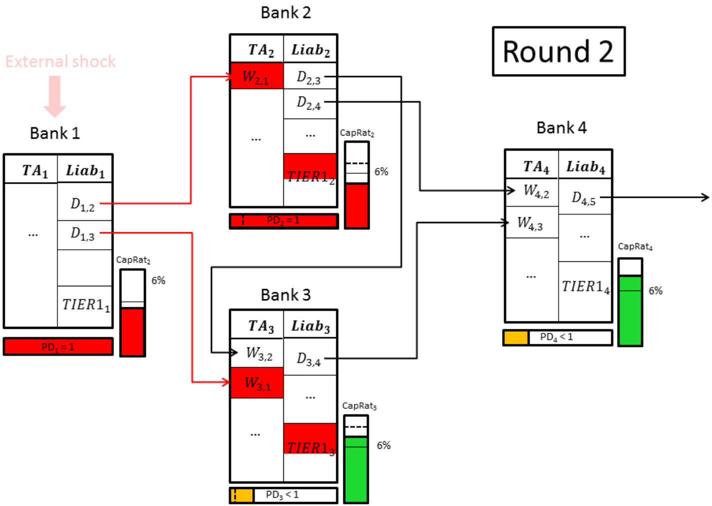
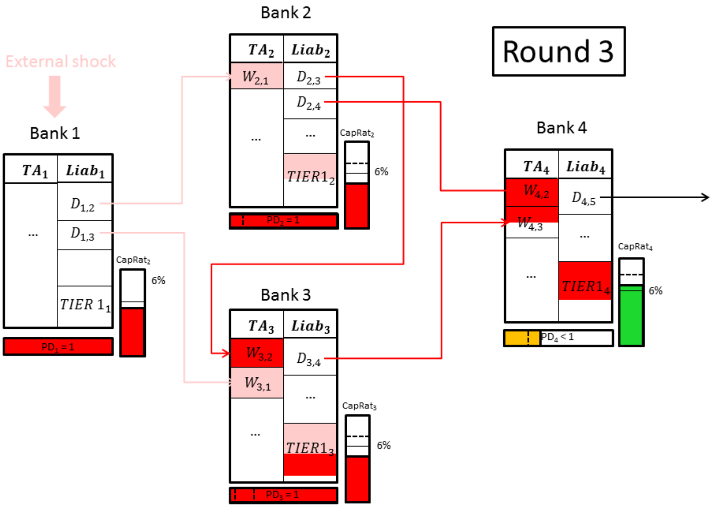
Appendix: Contagion process - Round 2



Appendix: Contagion process - Round 3



Appendix: IRB formula

Risk-weights are calculated using the IRB formula:

$$RW(PD, LGD, M) = 1.06 \cdot 12.5 \cdot LGD, \cdot \left(\mathcal{N}\left(\frac{\mathcal{N}^{-1}(PD) + \sqrt{\rho(PD)}\mathcal{N}^{-1}(q_{99.9\%})}{\sqrt{1-\rho(PD)}} \right) - PD \right), \cdot \frac{1 + b(PD)\cdot(M-2.5)}{1 - 1.5 \cdot b(PD)}$$

where $b(PD) = 0.11852 - 0.05478 \cdot ln(PD)$ and ρ is the *asset correlation*, which is defined by

$$\rho(PD) = \frac{1-e^{-50PD}}{1-e^{-50}} \cdot 0.12 + \left(1 - \frac{1-e^{-50PD}}{1-e^{-50}}\right) \cdot 0.24.$$

Appendix: Regression Results

Variables	Capital-Ratio	
log(Tier1-Capital over RWA)	**-2.005**	***
	(0.000)	
Depreciation and Adjustments over Equity	-0.001	
	(0.729)	
Administration Expenses over Total Assets	0.017	**
	(0.050)	
Return on Equity	-0.077	***
	(0.000)	
Cash and overn. Interb. Loans over Total Assets	0.031	***
	(0.002)	
Log Total Assets	0.309	***
	(0.000)	
(pseudo) R^2	0.136	

The regression is based on a panel-dataset containing 8288 observations and 6 periods. We control for regional fixed effects.

Appendix: Larger changes of $ln(CapRat_i)$

Some caution is necessary:

The formula

$$PD_{t-1}(i|A) + \beta_{caprat} \cdot (PD_{t-1}(i|A) - PD_{t-1}(i|A)^2) \cdot \Delta_t ln(CapRat_i)$$

holds only for infinitesimally small changes of $ln(CapRat_i)$. For larger changes of the capital ratio rules from calculus give the expression:

$$PD_t(i|A) = \frac{\left(\frac{CapRat_{i,t}}{CapRat_{i,t-1}}\right)^{\beta} \left(\frac{PD_{t-1}(i|A)}{PD_{t-1}(i|A)-1}\right)}{\left(\frac{CapRat_{i,t}}{CapRat_{i,t-1}}\right)^{\beta} \left(\frac{PD_{t-1}(i|A)}{PD_{t-1}(i|A)-1}\right) - 1}$$

Appendix: Illustration of the network