



Interconnectedness of the banking sector as a vulnerability to crises

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*The views expressed in this presentation do not necessarily represent those of the
ECB or the European Commission.*



Motivation

- ▶ Recent financial crises motivate new approaches to assess systemic risk along the time and cross-sectional dimension
 - ▶ Early-warning models (EWMs) to identify build-ups of widespread imbalances
 - ▶ Network perspectives to assess interdependence and cross-sectional risk
- ▶ In this paper
 - ▶ We bridge the gap by enriching a traditional EWM with network measures
 - ▶ Focus on not only cross-country networks, but also sectoral financial linkages within a country
 - ▶ Macro-network as a supervisory tool



The paper in a nutshell

Early-warning models

- ▶ To identify vulnerable states of a country's banking system
- ▶ Estimate the probability of being in a vulnerable state
- ▶ Set a threshold on the probability to optimize a loss function

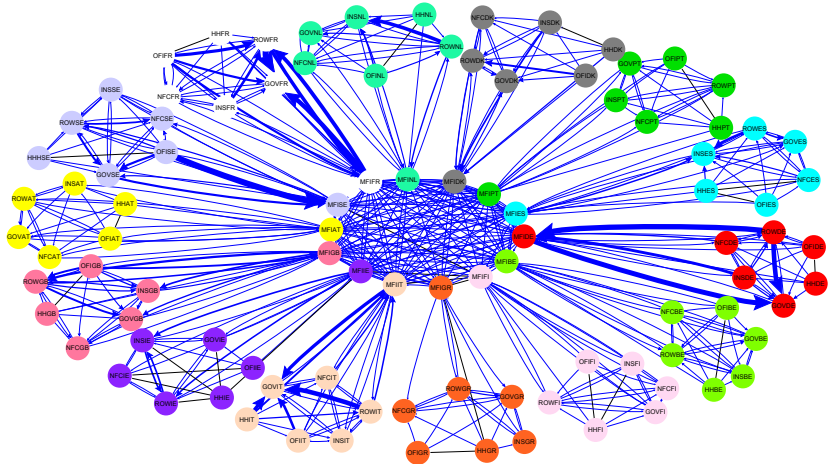
Macro-Network

- ▶ Financial network of institutional sectors for many economies:
 - ▶ NFC, MFI, OFI, INS, GOV, HH and ROW
- ▶ Financial instruments
 - ▶ Loans, deposits, debt and shares



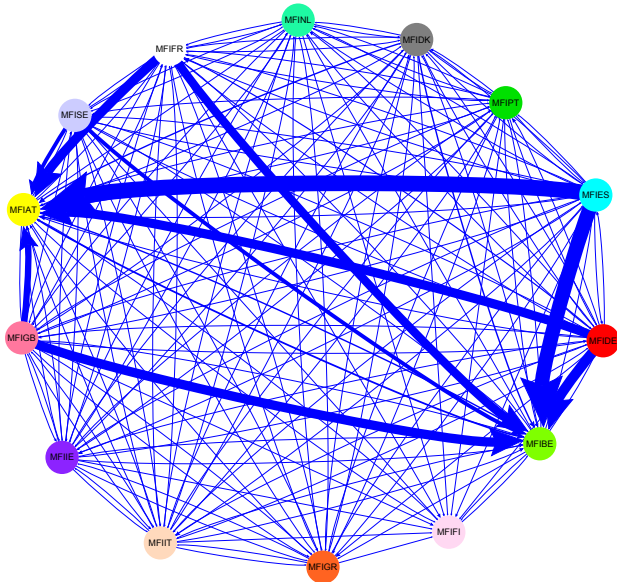
Macro-network

- ▶ Instrument: debt securities Q1 2009.





MFI cross-border linkages





Outline

- ▶ Related literature
- ▶ Data
- ▶ Methodology
- ▶ Results
- ▶ Conclusion



Related literature

- ▶ EWMs:
 - ▶ Frankel and Rose (1996), Kaminsky and Reinhart (1999), Borio and Lowe (2004), Lo Duca and Peltonen (2013), Sarlin (2013)
- ▶ Network analysis:
 - ▶ Fagiolo et al. (2010), Kubelec and Sa (2010), Billio et al. (2012), Chinazzi et al. (2013), Minoiu et al. (2013)
- ▶ Contagion effects via balance sheets:
 - ▶ Adrian and Shin (2008), Castrén and Rancan (2014)



Data

- ▶ Crisis events: ESCB Heads of Research Initiative (Babecky et al., 2013)
- ▶ Macro-financial indicators: international investment position, government debt and its yield and private sector credit flow, asset prices, business cycle variables... (Eurostat and Bloomberg)
- ▶ Banking sector indicators: measuring balance-sheet booms, securitization, and leverage (BSI and MFI from ECB)
- ▶ Macro-network:
 - ▶ the Euro Area Accounts (EAA from ECB)
 - ▶ the Balance Sheet Items statistics (BSI from ECB)
- ▶ The sample covers the period 2000–2013 and 14 European countries



Methods - Macro-network

We define a network as follows

- ▶ Nodes are the institutional sectors of the economy
- ▶ Linkages
 - ▶ Cross-borders (i.e. $MFI_{AT} \Leftrightarrow MFI_{BE}$): observed information in the BSI data
 - ▶ Domestic (i.e. $NFC_{AT} \Leftrightarrow INS_{AT}$): estimated with an improved maximum entropy (ME) using the EAA data

ME allows to estimate the linkages based on the relative shares of total assets and liabilities for each sector. Castrén and Rancan (2013) modify the algorithm to accommodate possessed additional information about the network structure at sectoral level.



Methods - Network measures

1. The Macro-Network is constructed for each time t and each financial instrument:
 - ▶ loans
 - ▶ deposits
 - ▶ debt securities
 - ▶ shares
2. For each Macro-Network we derive a set of network statistics
 - ▶ Degree-in (out) is the sum of all incoming (outgoing) linkages for a node
 - ▶ Betweenness captures the absolute position of a node in a network
 - ▶ Closeness is a measure of influence

Centrality measures are highly correlated to each other

3. Principal Component Analysis allows us to summarize centrality measures in parsimonious sets of relevant components



Methods - Evaluation criterion

- ▶ Apply usefulness criterion (Sarlin, 2013):

		Actual class I_j	
		Crisis	No crisis
Predicted class P_j	Signal	<i>True positive (TP)</i>	<i>False positive (FP)</i>
	No signal	<i>False negative (FN)</i>	<i>True negative (TN)</i>

- ▶ Find the threshold that minimizes a loss function that depends on policymakers' preferences μ between Type I errors ($T_1 = FN/(FN + TP)$) (missed crises) and Type II errors ($T_2 = FP/(TN + FP)$) (false alarms) and unconditional probabilities of the events P_1 and P_2

$$L(\mu) = \mu T_1 P_1 + (1 - \mu) T_2 P_2$$

- ▶ Define absolute usefulness U_a as the difference between the loss of disregarding the model (available U_a) and the loss of the model

$$U_a(\mu) = \min [\mu P_1, (1 - \mu) P_2] - L(\mu)$$



Methods - Evaluation & estimation

- ▶ Relative usefulness U_r is the ratio of captured U_a to available U_a , given μ and P_1

$$U_r(\mu) = U_a(\mu) / \min [\mu P_1, (1 - \mu) P_2]$$

Estimation:

- ▶ Pooled logit to identify vulnerable states (horizon: 8 quarters) with costs for missing a crisis > false alarms ($\mu = 0.8$)
- ▶ In-sample analysis to assess determinants
- ▶ Real-time analysis to assess predictability
 - ▶ Use investors' information set: quarterly data including publication lags
 - ▶ Estimation sample: 2000Q1-2005Q2, out-of-sample: 2005Q3-2013Q1 (t+1 projection)



Results - Macro-network

	Baseline	Macro-network variables			
	(1)	(2)	(3)	(4)	(5)
PC1 - MN - All		0.35***	0.36***	0.37***	0.44***
PC2 - MN - All			-0.13	-0.13	-0.16
PC3 - MN - All				0.06	-0.10
PC4 - MN - All					0.69***
AUC	0.73	0.79	0.79	0.79	0.80
$U_r(\mu = 0.7)$	0.12	0.25	0.29	0.30	0.38
$U_r(\mu = 0.8)$	0.23	0.37	0.39	0.42	0.49
$U_r(\mu = 0.9)$	0.23	0.38	0.36	0.36	0.36

The baseline model 1 includes macro-financial and banking-sector indicators. In models 2–5, we add the 1– 4 components computed with PCA on the centrality measures (Degree-in, Degree-out, Betweenness, Closeness) for the financial instruments.



Results - Cross-border linkages

	MN	Cross-border variables					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
PC1-All		0.32***	0.37***				
PC2-All		-0.11	-0.14				
PC3-All		-0.48***	-0.68***				
PC4-All			0.89**				
Loans				0.53***			
Deposits					0.54***		
Debt						0.40***	
Shares							0.37***
AUC	0.80	0.78	0.79	0.77	0.77	0.76	0.76
$U_r(\mu 0.7)$	0.38	0.21	0.21	0.18	0.15	0.17	0.14
$U_r(\mu 0.8)$	0.49	0.36	0.32	0.31	0.31	0.31	0.30
$U_r(\mu 0.9)$	0.36	0.32	0.34	0.33	0.35	0.29	0.31

Model 1 is the macro-net benchmark. Models 2-3 include for cross-border linkages PCs on all centrality measures for all financial instruments.

Models 2-5 include PCs computed separately for each instrument.



Results - Financial instruments

	Baseline	Varying financial instruments			
	(1)	(2)	(3)	(4)	(5)
PC1 - MN - Loans		0.64***			
PC1 - MN - Deposits			0.44***		
PC1 - MN - Debt				0.54***	
PC1 - MN - Shares					0.41***
AUC	0.73	0.78	0.77	0.78	0.76
$U_r(\mu = 0.7)$	0.27	0.27	0.18	0.21	0.17
$U_r(\mu = 0.8)$	0.23	0.40	0.31	0.35	0.31
$U_r(\mu = 0.9)$	0.23	0.29	0.32	0.32	0.32

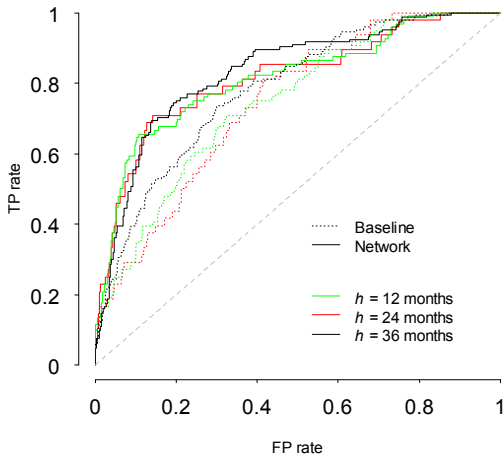
Model 1 is the baseline. In models 2–5, we add the the 1st PC on the centrality measures (Degree-in, Degree-out, Betweenness, Closeness) for separate financial instruments.



Results - robustness

Robustness exercises:

- ▶ policymakers' preferences μ
- ▶ forecast horizon (12/24/36 months)
- ▶ threshold λ

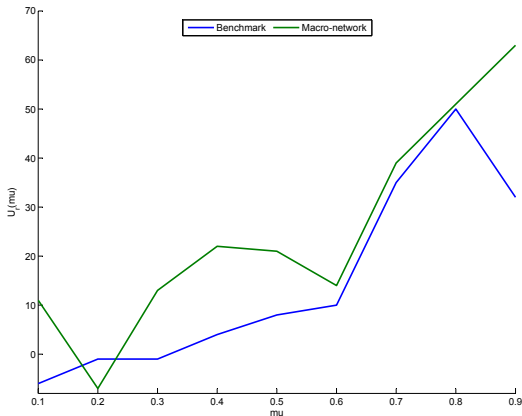




Results - Real-time analysis

- ▶ Real-time analysis to assess predictability:
 - ▶ Estimation sample: 2000Q1-2005Q2, out-of-sample: 2005Q3-2013Q1 ($t + 1$ projection)

AUC: 0.72 vs. 0.78





Conclusion

- ▶ We have shown that interconnectedness of the banking sector entails a vulnerability to crises
 - ▶ Cross-border linkages capture vulnerabilities to crises...
 - ▶ ...but including national sectoral linkages improves further...
 - ▶ ...which yields useful predictions
- ▶ Across financial instruments, most vulnerability descends from loans and securities
- ▶ As a policy tool, macro-networks also provide a useful visualization of banking sector linkages
<http://vis.risklab.fi/#/macronet>
- ▶ Future work
 - ▶ Transmission channels and instruments
 - ▶ Systematic approach to validating estimated networks



Thanks for your attention!