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

- Financial activities occur in a complex network of agents
  - Important to shed light on dynamics implied by financial flows in a wider network than among banks
- Systemic risk along time & cross-sectional dimensions
  - Early-warning models (EWMs) to identify build-up of risk
  - Networks to assess interdependence in the cross section
- This paper...
  - ...enriches an EWM with network measures
  - ...studies interconnectedness as a vulnerability to crises
    - Domestic *vs.* international linkages?
    - Difference among instruments?
    - Non-linear effects?

EWM & macro-network

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

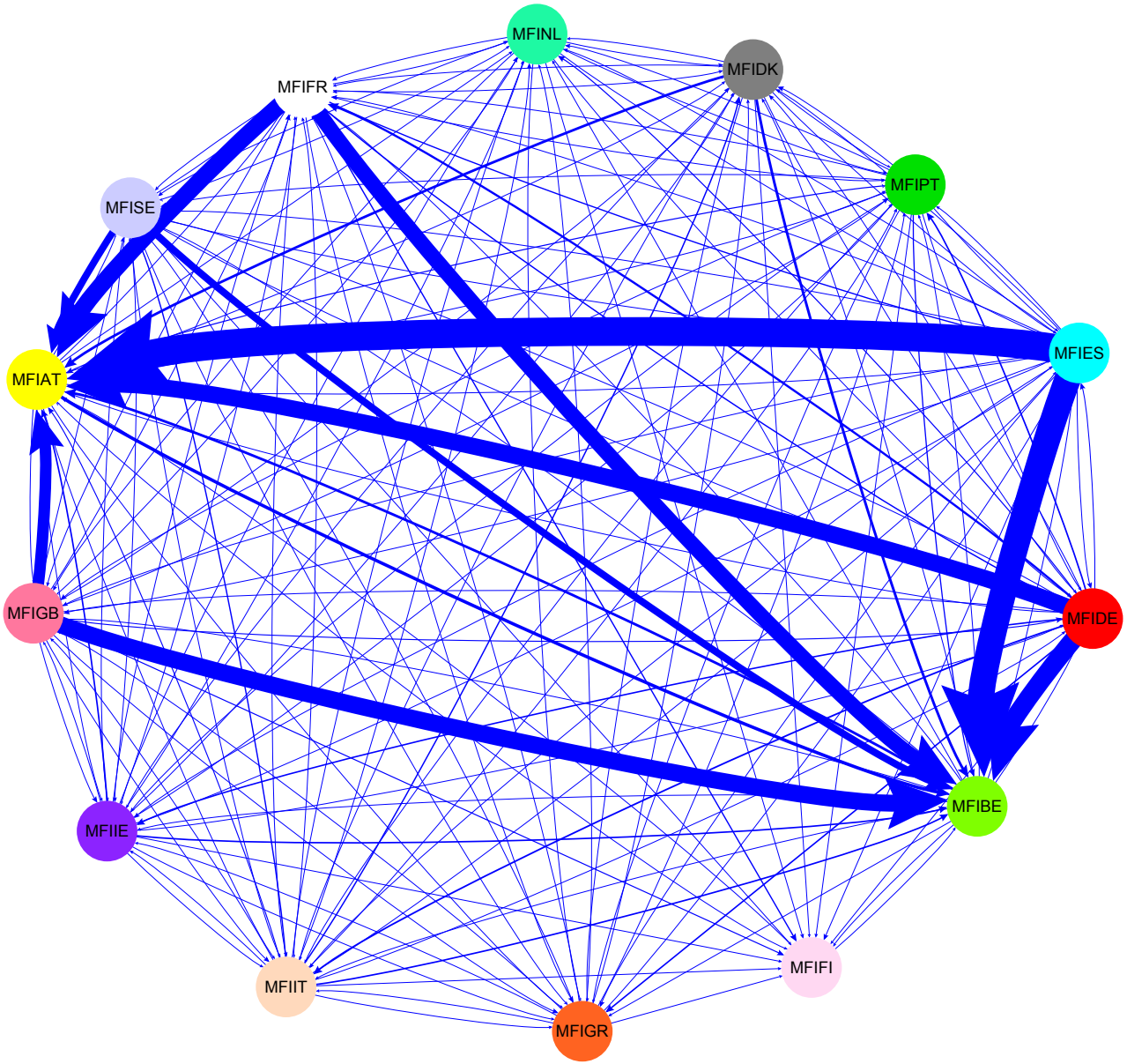
Macro-network

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

MFI as a nexus of risks

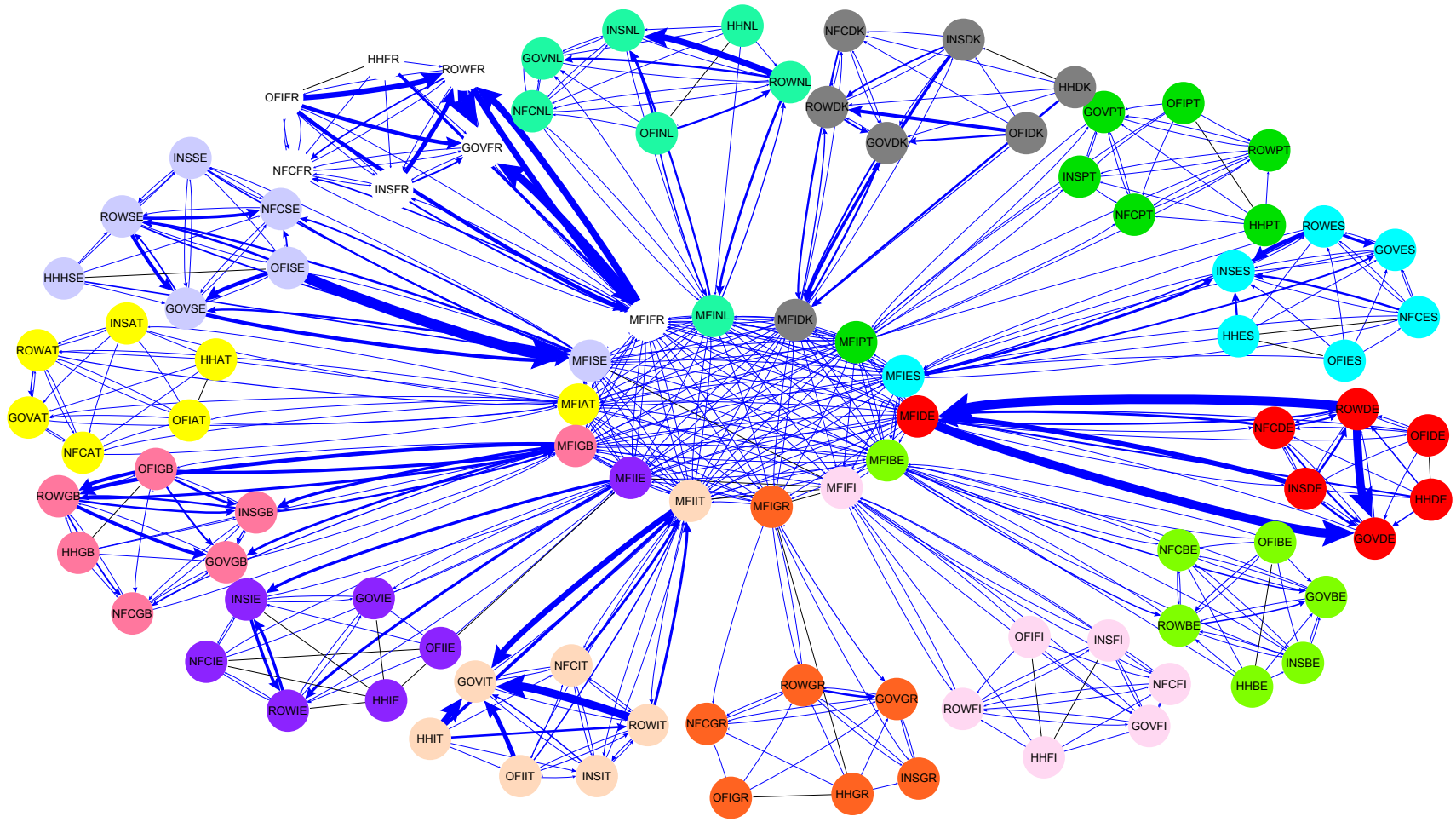
- Macroeconomic shocks in input-output
  - Demand-side shocks propagate upstream (input suppliers)
  - Supply-side ... propagate downstream (customer industries)
- Financial shocks in the macro-network:
  - Lability-side: propagate to shareholders, debtors, depositors
  - Asset-side: propagate (downstream) to creditors
  - MFI vulnerable to shocks on both sides of the balance sheet and the two are tightly intertwined.
- MFI a direct holder & intermediary depending on instrument:
  - Loans: Main sector extending (Credit risk)
  - Deposits: Important source of funding, yet depositors may easily withdraw money (Funding and liquidity risks)
  - Debt securities & shares: Hold assets valued at market prices (market risk) and issues bonds & equity (funding risk)

Cross-border linkages



Macro-network

- Instrument: debt securities Q1 2009. [1]



Outline

- Related literature
- Data & methods
- Results
- Conclusion

Related literature

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

Data

- Sample spans 2000Q1–2013Q4 for 14 European countries
- 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)

Methods - Macro-network

We define a network as follows [1]

- 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

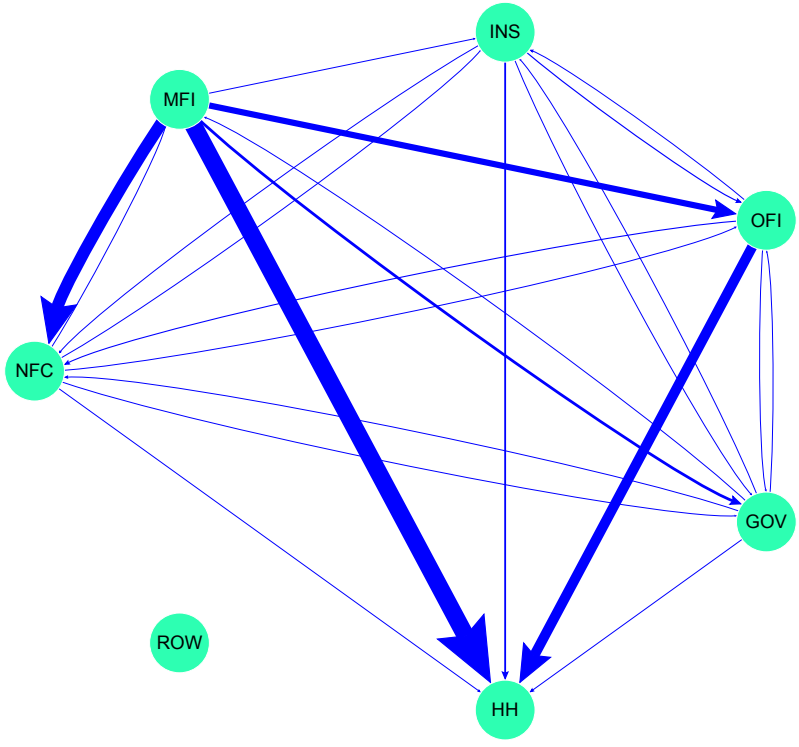
Methods - Macro-network

- Cross-border linkages
  - Increased MFI cross-border flows with the single currency but less financial integration across other sectors
  - Exception: Cross-border links between MFI & GOV on debt securities, yet data scarce & discontinuities impact centrality
  - ROW partially accounts for 'missing' linkages across borders
- Domestic linkages
  - ME to estimate links with relative shares of total assets & liabilities for each sector, and accommodate possessed additional information as in Castrén & Rancan ('13)
  - Heterogeneity in links at country level due to structural differences (e.g., INS and OFI important in Ireland & Netherlands, much less in Spain & Italy)
  - ME assumptions are quite reasonable for sector-level data

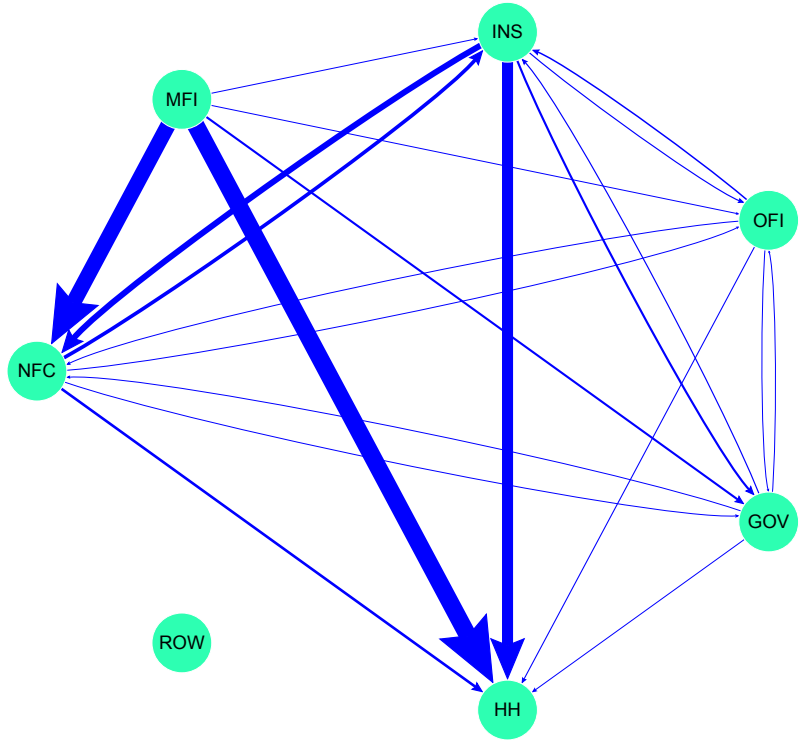
Methods - Macro-network

Loans: ∼Complete network, large (MFI-NFC) & small (OFI-NFC)

Real



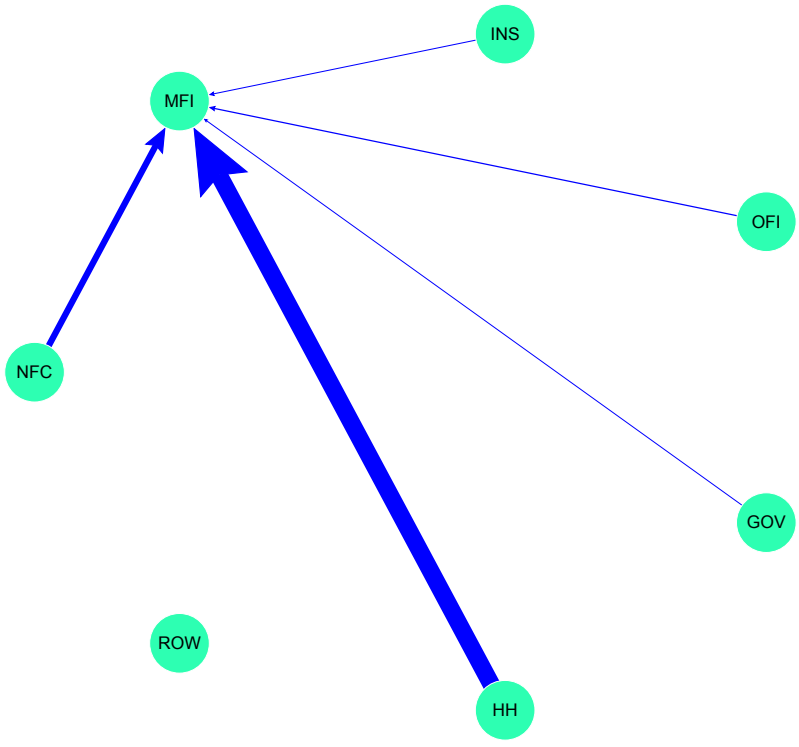
Estimated



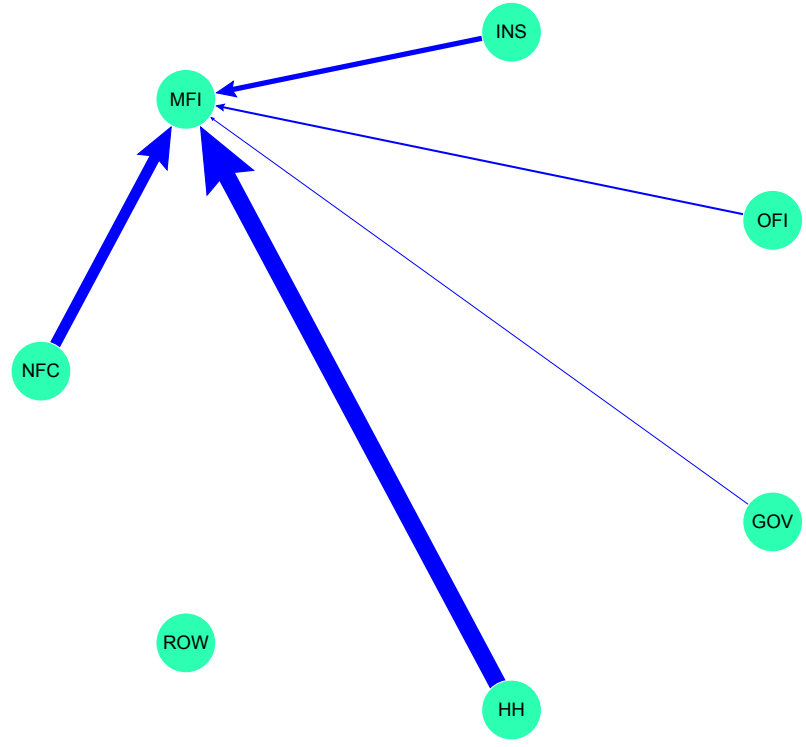
Methods - Macro-network

Deposits: Incomplete network

Real



Estimated



Methods - Network measures

1. A macro-network for each time t and financial instrument:
   - loans
   - deposits
   - debt securities
   - shares
2. For each macro-network we derive a set of network measures
   - Degree-in (out): sum of a node's incoming (outgoing) links
   - Betweenness: a measure of influence of a node ("hub")
   - Closeness: a measure the absolute position of a node

   Yet, centrality measures are highly correlated with each other
3. PCA reduces centrality to fewer but representative components

Methods - Evaluation criterion

- Apply usefulness criterion (Sarlin, 2013):

		Actual class I_j: Crisis	Actual class I_j: No crisis
Predicted class P_j	Signal	*True positive (TP)*	*False positive (FP)*
	No signal	*False negative (FN)*	*True negative (TN)*

- 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

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

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

- MFIs more vulnerable to credit and market risks, yet...
- accounting for all instruments provides more precise signals

	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. Models 2–5 add the 1st PC on the centrality measures (Degree-in, Degree-out, Betweenness, Closeness) for separate financial instruments.

Results - Non-linearity

Structure of the financial network and the resilience of the system

- Non-conclusive evidence: Acemoglu et al. ('15) show non-monotonic contagion effects of shocks
- Non-linearity effects are confirmed also in our setting

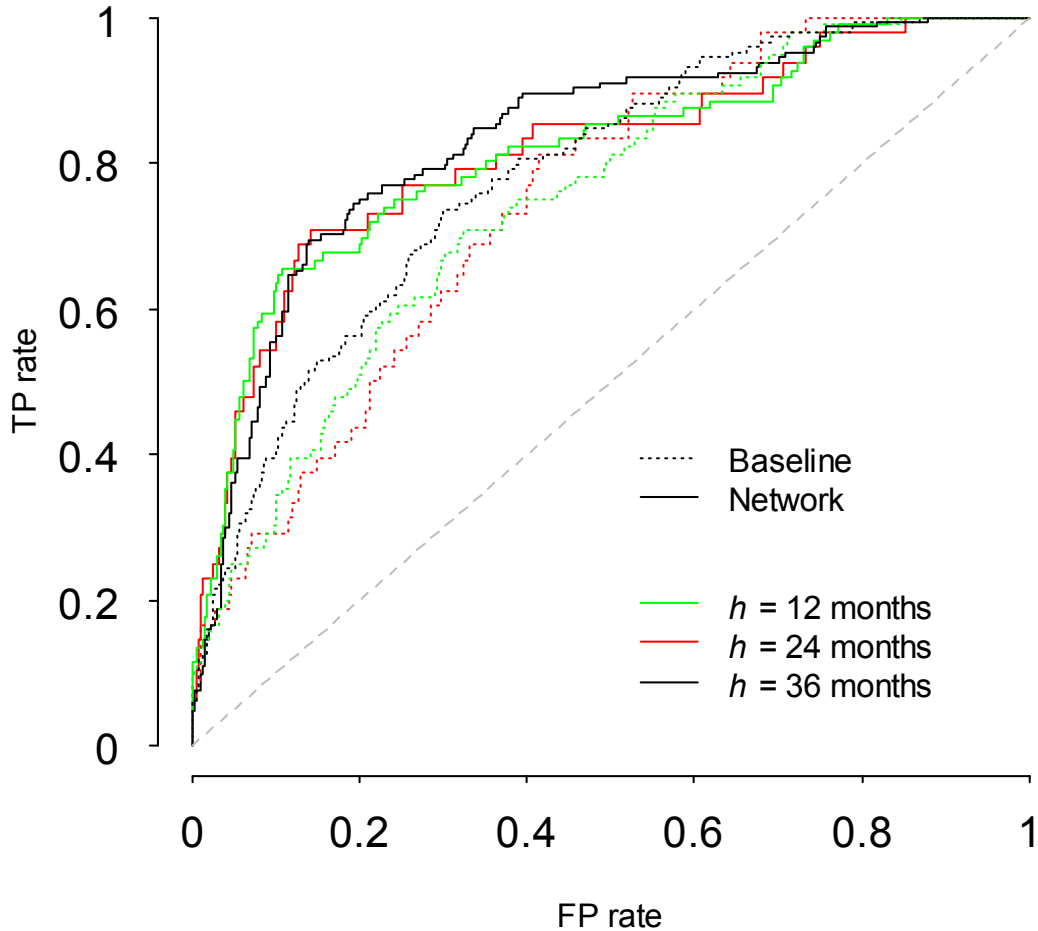
	MN	Loans	Deposits	Securities	Shares
PC1*[above p75]		1.10***	0.38**	0.64***	0.60***
PC1*[between p25 – 75]		2.66***	2.69***	3.31***	3.54***
PC1*[below p25]		0.21	0.38	-0.10	-0.45
AUC	0.80	0.82	0.78	0.82	0.81
$U_r(\mu = 0.7)$	0.38	0.36	0.21	0.30	0.27
$U_r(\mu = 0.8)$	**0.49**	**0.45**	**0.34**	**0.41**	**0.39**
$U_r(\mu = 0.9)$	0.36	0.38	0.28	0.41	0.40

MN includes all centrality measures & all instruments. Others include all centrality measures for individual instruments interacted with dummies.

Results - Robustness

Robustness exercises:

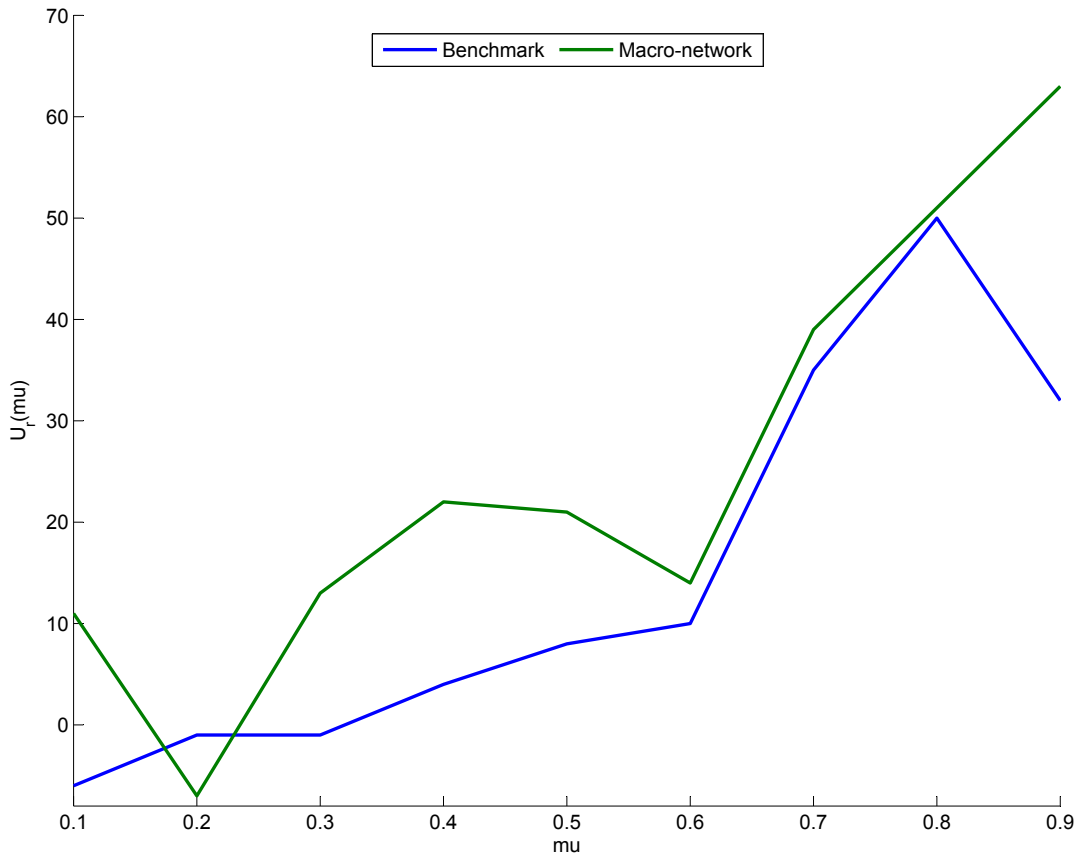
- policymakers' preferences μ
- forecast horizon (12/24/36 months)
- threshold λ



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

Summary

- Interconnectedness of the banking sector entails a vulnerability
  - Cross-border linkages capture vulnerabilities to crises...
  - ...and larger domestic sectoral linkages amplifies vulnerability...
  - ...which yields useful predictions
- Most vulnerability descends from loans and debt securities
- Non-linearity effects are confirmed also in our setting

To conclude

- Macro-networks: MFI vis-à-vis domestic sectors & multi-layer
- But this is only a first step, future research is needed to
  - Better understand the underlined macro-financial linkages
  - Deeper investigate sources of bank risk & their interactions
  - Evaluate how risks are shared across sectors
  - More detailed cross-border exposures

Thanks for your attention!