EUROPEAN CENTRAL BANK

EUROSYSTEM

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Measuring Systemic Risk in the European Banking and Sovereign Network

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Motivation

- **Regulatory perspective** (e.g. application of SIFI buffers)
  - need for bank-level tools to understand systemic risk contributions of individual banks

- **Reversal of financial market integration in Europe** during the global financial crisis
  - need for tools to measure and monitor financial fragmentation

- **Feedback loop between weak banks and fiscally strained sovereigns**, particularly at the height of the European sovereign debt crisis
  - need to incorporate the interdependence between banks and sovereigns in the analysis

This project…

- Provides a framework for estimating **time-varying systemic risk** contributions of individual banks

- **Estimates** systemic risk contributions for 51 large **European banks** over 2000q1-2013q3, and **visualises** the estimated tail dependences

- It explicitly takes into account the **interconnectedness** of relevant entities. Moreover, it also incorporates both the sovereigns and banks into an estimated tail risk network.

- Shows how **banking sector fragmentation** and **sovereign-bank interaction** evolved during the European sovereign debt crisis

Related literature

Measurement of systemic risk contributions

- Acharya, Pedersen, Philippon, and Richardson (2010); Adrian and Brunnermeier (2011); Brownlees and Engle (2012),…
- Extension of Hautsch, Schaumburg, and Schienle (2012); Hautsch, Schaumburg, and Schienle (2014)

Sovereign-bank interlinkages

- Ejsing and Lemke (2011), Alter and Schüler (2012), Arnold (2012), Bruyckere, Gerhardt, Schepens, and Vennet (2013), Alter and Beyer (2014), and Correa, Lee, Sapriza, and Suarez (2014)

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Data definitions and sources

1) **Banks** (source: Bloomberg)
   - 51 large listed European banks, covering 70% European banking sector
   - Balance sheet data: leverage (total assets over total equity), loan loss reserves, the P/B ratio, ROE, ROA, the loan-to-deposit ratio, the ratio of net short-term borrowing to total liabilities, the cost-to-income ratio and total assets.
   - Asset price data: equity prices and 5-year CDS spreads

2) **Sovereigns** (Source: Bloomberg)
   - 17 sovereigns, corresponding to the countries where the banks in the sample are headquartered: Austria, Belgium, Cyprus, Germany, Denmark, Spain, Finland, France, Greece, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Sweden and the UK.
   - 10-year benchmarks bonds, slope of the yield curve, 5-year CDS spreads.

3) **Markets** (Source: Bloomberg)
   - Euribor-OIS spread (liquidity and credit risk) and the VDAX index (risk aversion)

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Implementation: Two-stage procedure

1st stage:

- **Estimate tail dependence network**. Beyond bank-specific balance sheet characteristics and market prices, we incorporate **loss exceedances of other banks and sovereigns** as a risk drivers
- Prediction yields a bank's estimated **Value-at-Risk**

2nd stage:

- **Estimate the marginal systemic risk contribution.** Beyond bank-specific variables (leverage and annual growth in total assets), we include estimated **network characteristics** (log degree) as factors impacting marginal systemic risk contribution
- **Calculate the "realized" systemic risk contributions** as a product of the estimated **VaRs** and the **marginal systemic risk contributions**

1st stage: Tail-dependence networks

- We adapt the approach in Hautsch, Schaumburg, and Schienle (2012) by allowing the tail dependence network to vary over time and by incorporating sovereigns as potential risk drivers
- The main idea of constructing tail-dependence networks is to empirically determine a network link from institution / sovereign *j* to institution / sovereign *i*, whenever **the tail risk of *i* is (positively) affected by the distress of *j***
- Denoting the equity or CDS return of bank/sovereign *i* by$-X_i^t$, the tail risk of *i* is reflected by its conditional VaR, VaR_t^i given a set of i-specific risk drivers R_t^i

$$Pr(-X_i^t \geq VaR_{q,t}^i | R_t^i) = q$$

- The distress of a bank/sovereign is measured by the corresponding return being below its empirical 10th percentile

1st stage: Tail dependence networks

- Specifying VaR_t^i as a linear function of the risk drivers yields

$$VaR_t^i = \alpha_1^i + \alpha_1^i Z_{t-1}^i + \alpha_2^i N_t^i$$

  where Z_{t-1}^i are macro-financial state variables as well as bank *i* specific balance sheet characteristics. N_t^i denote a vector of loss exceedances with elements $N_{t,j}$ for j ≠ i denoted $N_{t,j} = (X_t^j \leq \hat{Q}_{0.1}^j)$

- Due to large number of potential regressors, we a **use model shrinkage** approach to identify the subset of relevant *i*-specific loss exceedances, denoted by $N_t^{(i)}$ from the set of potential network influences N_t^i
- In particular, we use a weighted version of the least absolute shrinkage and selection operator (**LASSO)** approach for quantile regression as introduced by Belloni and Chernozhukov (2011)

2nd stage: Marginal systemic risk

- Thus, the effect of the estimated $\widehat{VaR}_t^{i,t_0}$ on VaR_t^s at time point t (based on estimation window starting in t_0) can be estimated using

$$VaR_t^s = \beta^{t_0}\left(B_t^i, net_t^{i,t_0}\right)\widehat{VaR}_t^{i,t_0} + \gamma^i + \theta Z_t^s$$

  where B_t^i are bank *i* specific balance sheet characteristics, net_t^{i,t_0} network centrality measures, γ^{i,t_0} fixed effects and Z_t^s macro-financial state variables

- When estimating the time-varying **marginal systemic risk contributions**, we set β^{t_0} as linear in its components (to keep the approach computationally tractable)

$$\beta^{t_0}\left(B_{t-1}^i, net_t^{i,t_0}\right) = \delta_0^{g,t_0} + \delta_1^{t_0} B_{t-1}^i + \delta_2^{t_0} net_t^{i,t_0}$$

  where $g = 1,2,3$ is based on ex-ante leverage and size

2nd stage: Realized systemic risk

- After estimating the Value-at-Risk, $\widehat{VaR}_t^{i,t_0}$ and the marginal systemic risk contribution, $\widehat{\beta^{t_0}}$, the **"realized" systemic risk contribution** of bank *i* can be calculated as

$$\hat{\beta}_t^{s|i} := \widehat{\beta^{t_0}}\left(B_{t-1}^i, net_t^{i,t_0}\right)\widehat{VaR}_t^{i,t_0}$$

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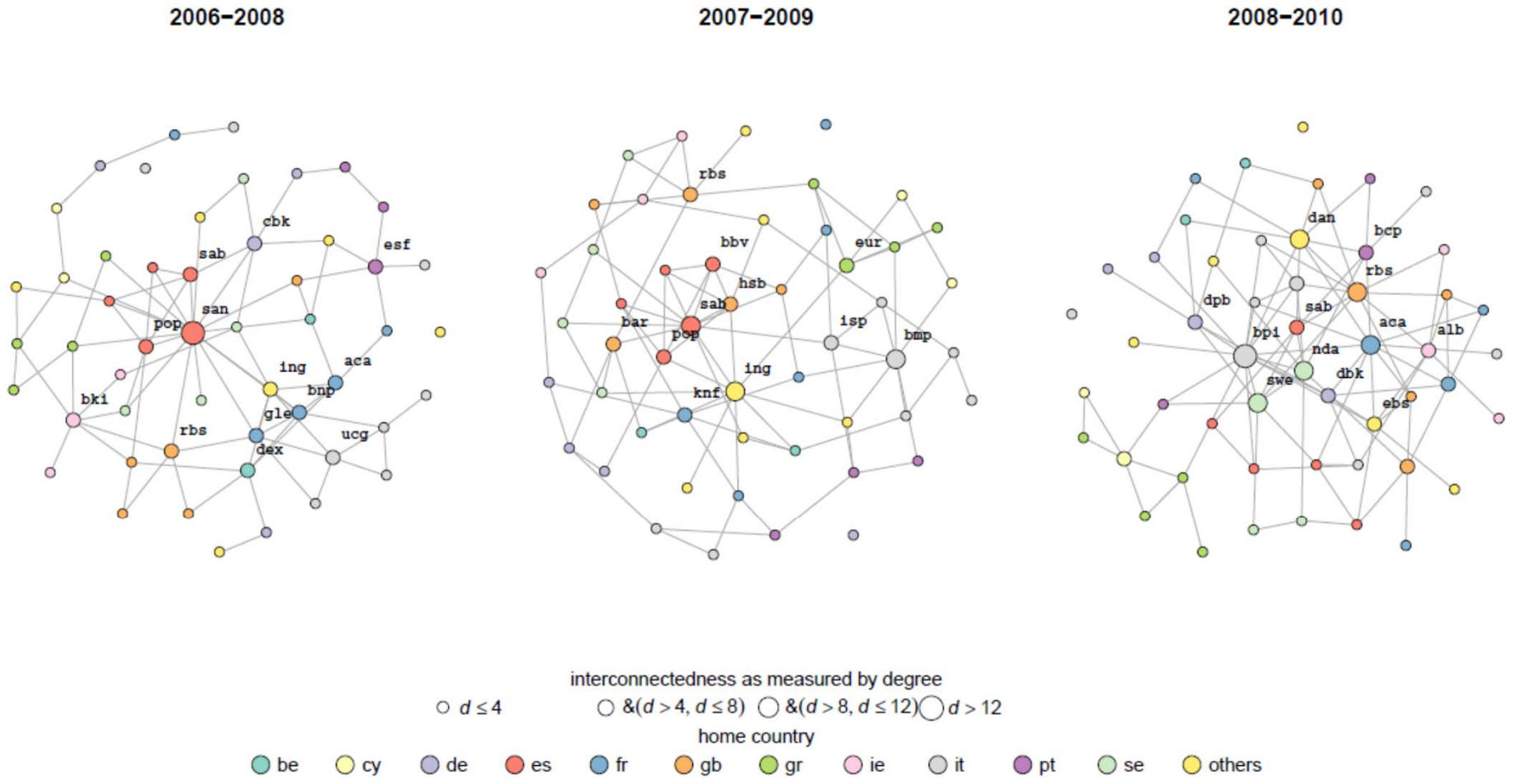
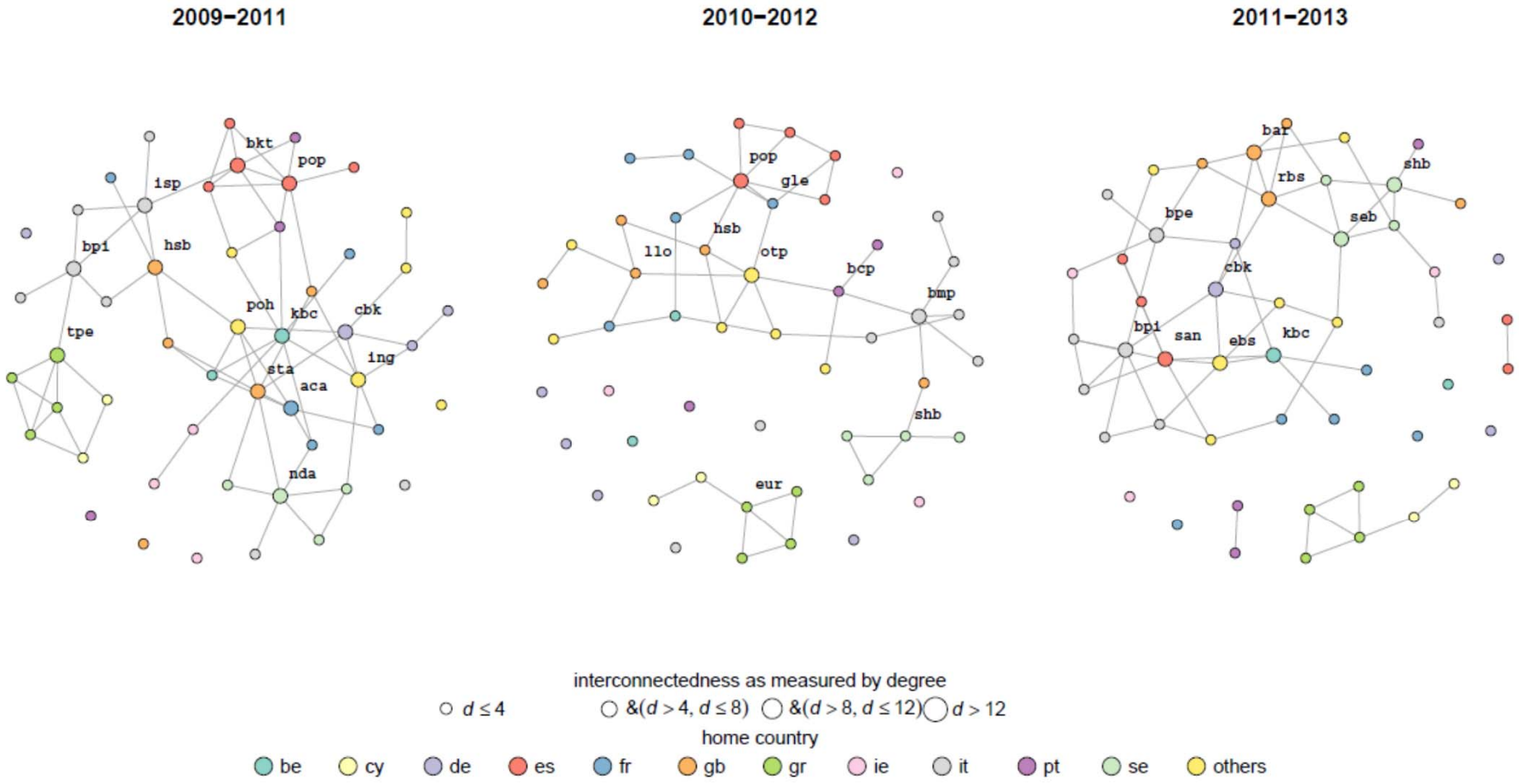
Estimated tail dependence network, 2006-10



Estimated tail dependence network, 2009-13

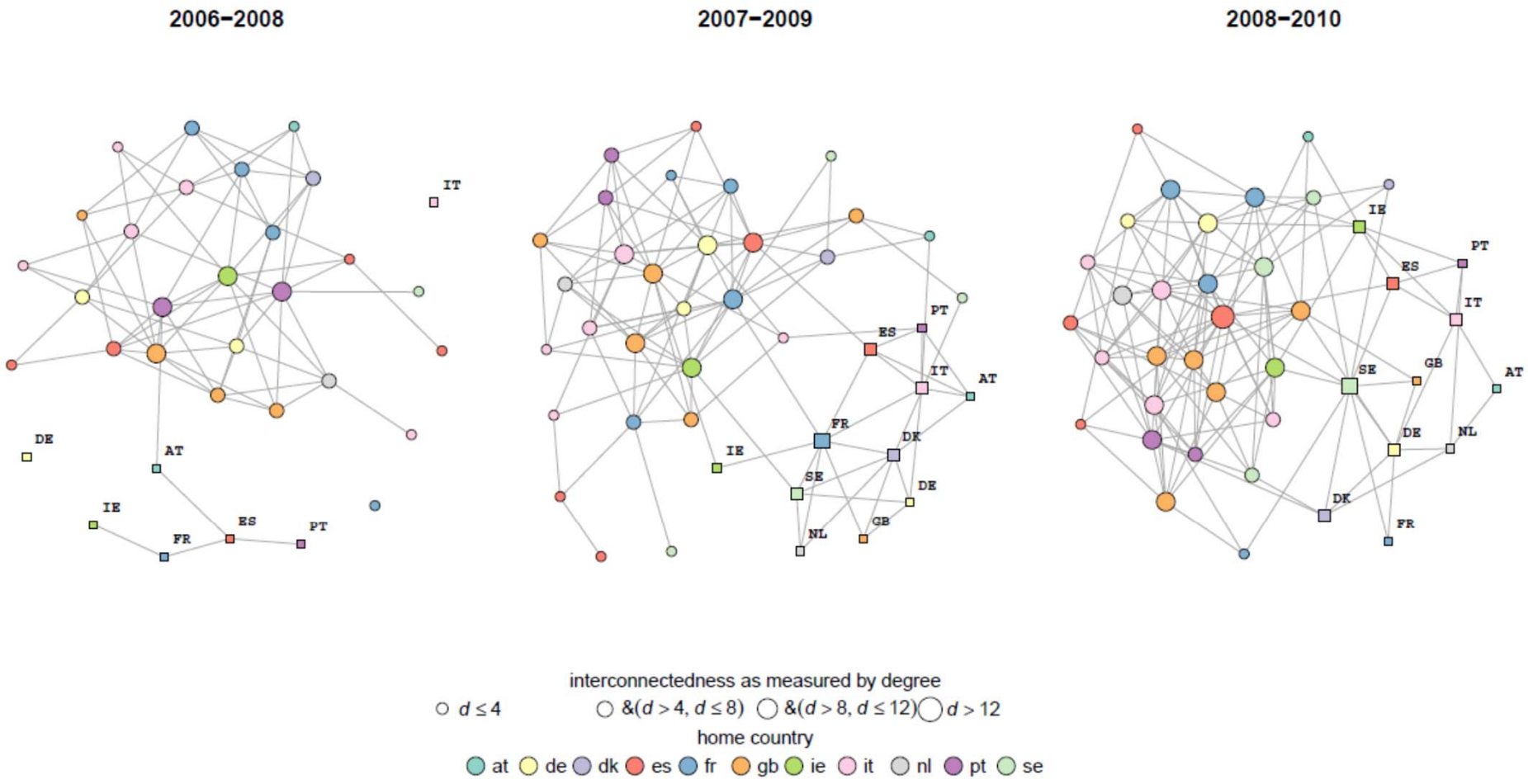


Financial fragmentation, equity price tail dependence

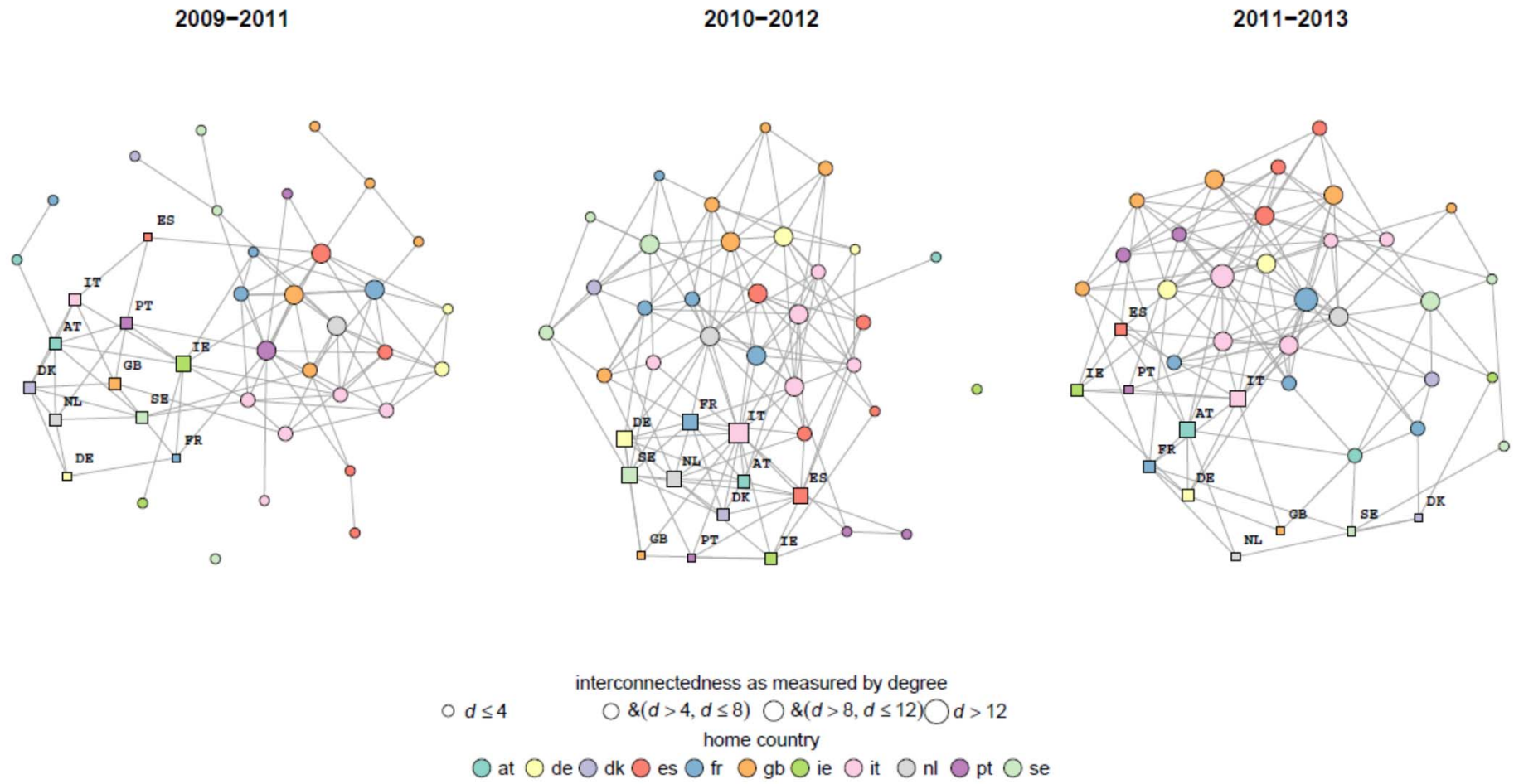
		Share of domestic links		
	Network density	All	Crisis countries	Other countries
2006	0.07	0.34	0.32	0.10
2007	0.07	0.37	0.35	0.17
2008	0.08	0.28	0.20	0.15
2009	0.06	0.47	0.45	0.25
2010	0.04	0.52	0.56	0.30
2011	0.05	0.45	0.44	0.17

Note: Crisis countries refers to group of countries composed of CY, ES, GR, IE, IT, and PT. Other countries refers to the average over all other countries.

Estimated bank-sovereign tail risk network, 2006-10



Estimated bank-sovereign tail risk network, 2009-13

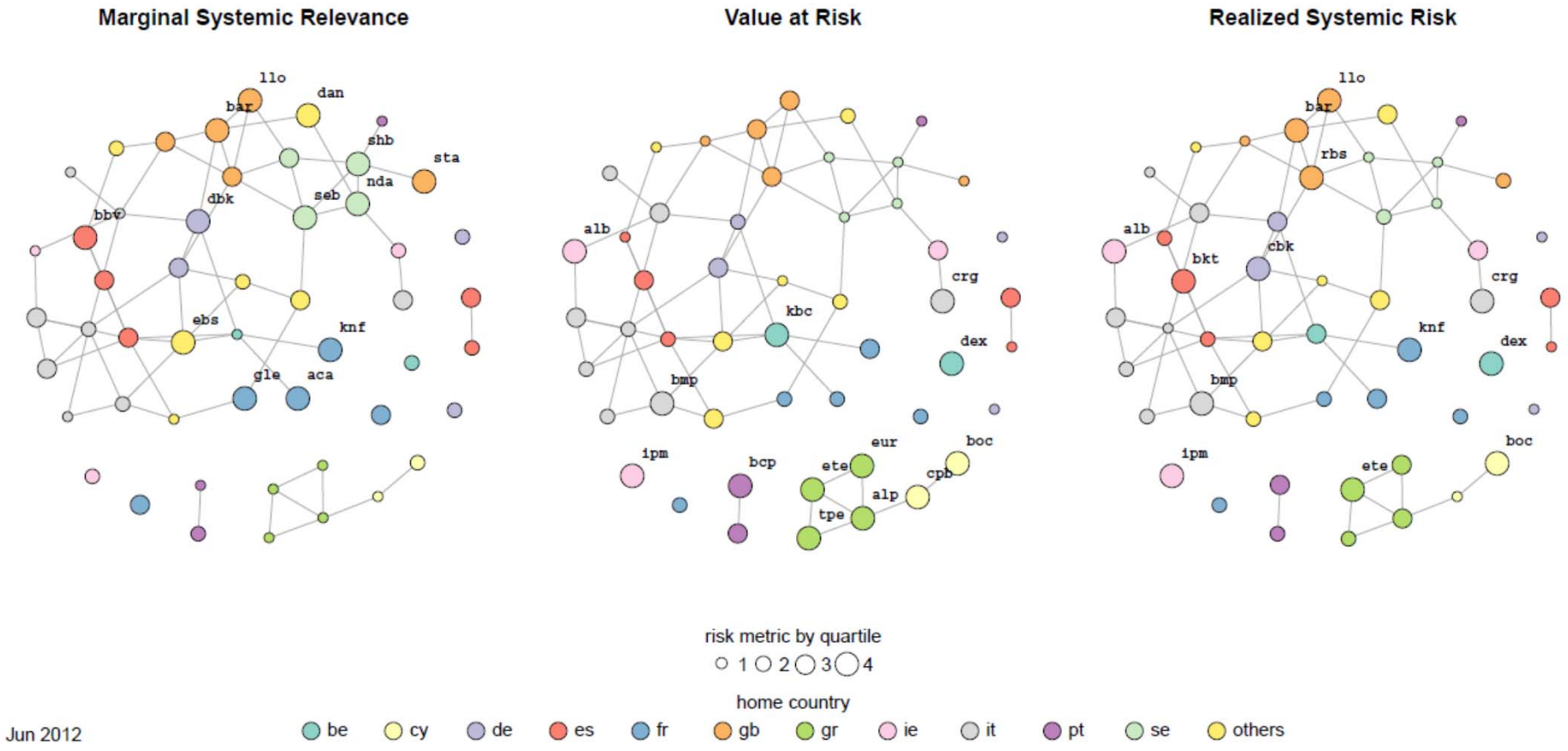


Financial fragmentation, CDS spread tail dependence

	Network density	Share of domestic links	Share of sovereign-bank links
2006	0.13	0.22	0.01
2007	0.14	0.20	0.06
2008	0.18	0.20	0.10
2009	0.12	0.30	0.13
2010	0.17	0.32	0.21
2011	0.18	0.23	0.19

Note: The LASSO procedure for selecting the relevant risk drivers when constructing the underlying networks penalize sovereign CDS returns to the same extent as banks CDS returns. The share of domestic linkages only takes into account connections between banks.

Estimated systemic risk contributions, June 2012



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Conclusions

- The paper provides a framework for estimating and visualising time-varying systemic risk contributions, and applies it to 51 large European banks over 2000q1-2013q3
  - It takes into account the tail risk interdependencies and the centrality of relevant entities in modelling systemic risk contributions
  - It incorporates both the sovereigns and banks into an estimated tail risk network

- It shows how banking sector fragmentation and sovereign-bank linkages evolved over the European sovereign debt crisis
  - It provides some indication that the fragmentation of the European financial system has peaked and that the reintegration has started

- It illustrates the complexity of robustly deriving systemic risk contributions of individual banks