

An aggregation operator for measuring cross-sectional and cyclical systemic risk

Systemic risk aggregation

Systemic risk dimensions

- Cyclical systemic risk
- Cross-sectional systemic risk

Risk indicators into probability

- Signaling: univariate indicators
- Non-linear approaches for combining indicators
- Ensemble learning

Interlinkages into centrality

- In, out & total strength
- Betweenness, closeness, eigenvector centrality
- DebtRank

How to aggregate risk levels of individual components and interlinkages among components in a general model?

Aggregating interconnected risk

Characteristics of interconnected risk

- A hierarchical system of components
- Risk levels for individual components
- Interlinkages among the components

Centrality measures as aggregation functions

- Existing measures aggregate links with simple operators (mean, min, max)
- We propose combining probabilities and links with aggregation operators
- Choquet integral as a non-linear and non-additive aggregation of networks

RiskRank provides...

- ...a general-purpose measure of interconnected risk
- ...a measure that also aggregates upward in the hierarchy
- ...a decomposition into individual, direct & indirect effects
- ...multiple indirect effects and feedback loops through dynamic iteration

RiskRank for measuring interconnected risk

- $x_c \in [0,1]$: the risk level of component c
- $l(c_i, c_j) \in [0,1]$: interlinkage between components i and j
- $v(c)$: Shapley-index (average contribution of fixed component c)
- $w(c) \in [0,1]$: importance of individual risk. For $w(c)=1$ a monotone increasing function of the interlinkages.

$$RR_c = \underbrace{w(c)x_c}_{\text{Individual effect of component } c} + \underbrace{\sum_{i=1}^n (v(c_i) - \frac{1}{2} \sum_{j \neq i} l(c_i, c_j)) x_i}_{\text{Direct effect of component } i \text{ on } c} + \underbrace{\sum_i \sum_{j \neq i} l(c_i, c_j) \prod (x_i, x_j)}_{\text{Indirect effect of component } j \text{ via } i \text{ on } c}$$

Applications of RiskRank

- **Example 1: Countries**
 - **Sample:** 15 EU countries, '80Q1-15Q1
 - **Individual risk:** Logit model, 14 macro-financial indicators
 - **Linkages:** BIS Locational Banking Stat.
 - **Output:** Country and system-level measures of interconnected risk
- **Example 2: Banks**
 - **Sample:** 500+ EU banks, '00Q1-'15Q1
 - **Individual risk:** Logit model, 24 bank-specific and country-level indicators
 - **Linkages:** EVT-based tail dependence
 - **Output:** Bank, country and system-level measures of interconnected risk

Ex. 1: RiskRank as a network

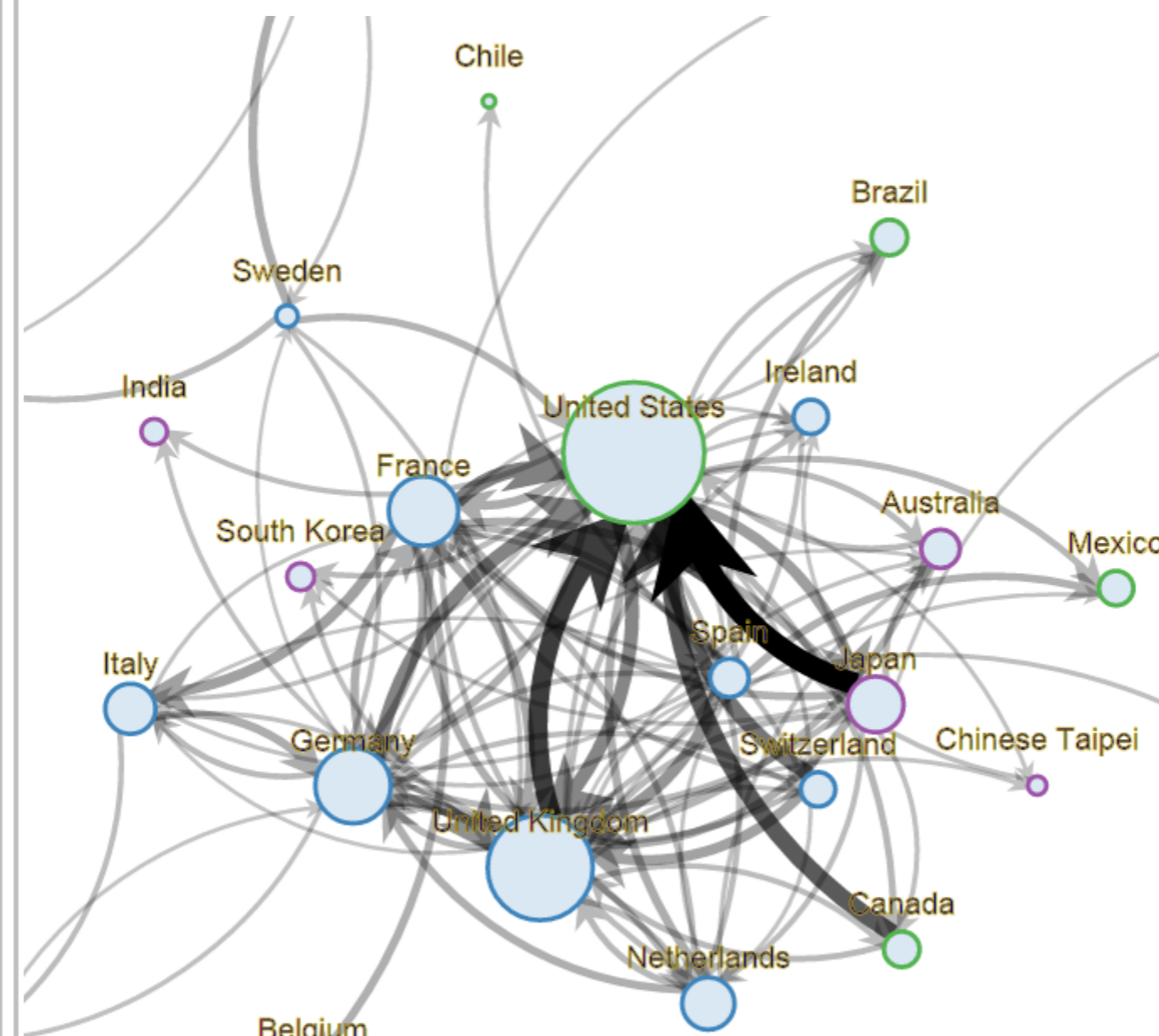


Figure 1. An illustration of a network in which node size represents risk levels and link width/darkness strength of interlinkages.

Ex. 1: Predictive performance

μ	Individual		RiskRank	
	$U_r(\mu)$	AUC	$U_r(\mu)$	AUC
0	0%	0.915	0%	0.937
0.1	-6%	0.915	-8%	0.937
0.2	-3%	0.915	-2%	0.937
0.3	6%	0.915	7%	0.937
0.4	12%	0.915	12%	0.937
0.5	15%	0.915	27%	0.937
0.6	25%	0.915	39%	0.937
0.7	44%	0.915	50%	0.937
0.8	60%	0.915	64%	0.937
0.9	73%	0.915	75%	0.937
1.0	0%	0.915	0%	0.937

Table 1. Out-of-sample predictive performance of a country-level standard logit model and its aggregation with RiskRank.