# Long-range Key Borrower Index for Evaluation of Power of Countries as Borrowers

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# About our work

- **We propose both theoretical and empirical model for evaluation of agents' power in network structures;**
- **Network approach as an intuitive representation of the financial relationships (lender-borrower interactions);**
- **How stable this network structure is? How we can evaluate the contribution of each element in a systemic risk?**

# Motivation

- **Systemic risk can be defined as joint distress of several financial institutions with externalities that disrupt the real economy**

IMF, BCBS, G20, ECB:

"A risk of disruption of financial services that is caused by an impairment of all or parts of the financial system and has the potential to have serious negative consequences for the real economy"

- **Systemically important financial institutions (SIFIs)**

"A financial institution can be considered to be systemically important if its failure or malfunction would have a significant, adverse impact on the financial system" (Praet, 2010)

# Research objective

- **The challenge is:**
  - to construct a measure of systemic risk
  - to apply it to real financial markets

**To develop an approach for detection of key borrowers in a financial markets which could influence the stability of the system as a whole**

# Related literature

- **Indicator-based approach** (Thomson, 2009 , Patro et al., 2013, BCBS, 2013, ECB, 2015, IMF, 2015)

- **Structural approach** (Hartmann et al. 2005, Allenspach and Monnin, 2006, Segoviano, Goodhart, 2009, Acharya et al., 2010, Zhou, 2010, Adrian, Brunnermeier, 2010, Drehmann, Tarashev, 2011)

- **Network approach** (Allen, Gale, 2000, von Peter, 2007, Allen, Babus, 2009, Martinez-Jaramillo et al., 2014, Leonidov, Rumyantsev, 2013, Aleskerov et al. 2014)

***Main instruments:***

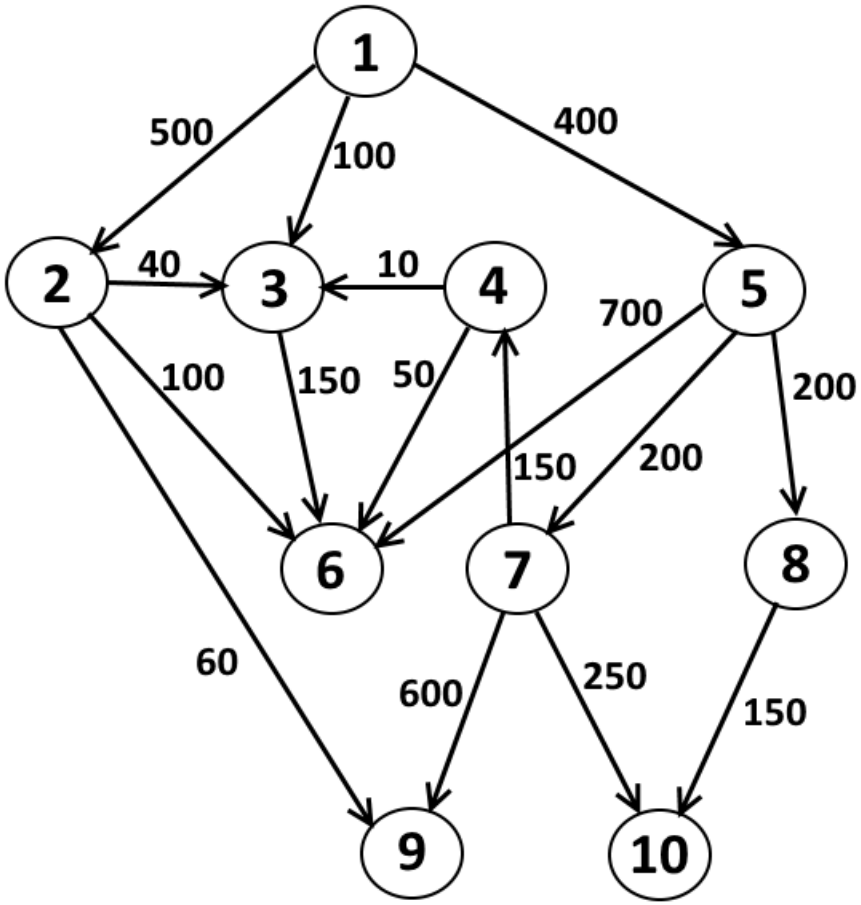
- centrality measures;
- simulations;
- indices based on power analysis.

# Our approach

- **Intensities of interactions;**
- **Multistep interactions;**
- **Size of vertices relative to those with whom they interact**

**Our methodology allows us to consider the interaction between a lender and a borrower not just on the first level, but also on some levels beyond**

# Hypothetical example




- Values on the edges represent the amount of loan that one element gives to another
- Most of approaches consider lenders 6 and 9 are the most powerful;
- None of existing measures consider the agent 10 as the key borrower.

# Methodology (1)

Our methodology takes into account *s*-long-range interactions. The parameter *s* that defines how many "layers" are examined for each lender.

1. Form **loan matrix** $A = [a_{ij}]$ , where $a_{ij}$ is the loan amount member *i* to member *j;*

2. ***Direct influence****:* construct a matrix $C = [c_{ij}]$ with respect to the matrix A and predefined quotas and consider only groups that contain only direct borrowers of the lender *l*

$$c_{ij} = \begin{cases} \dfrac{a_{ij}}{\min\limits_{\Omega(i) \subseteq N_i | j \in \Omega_p(i)} \sum_{l \in \Omega(i)} a_{il}}, if\ j \in \Omega_p(i) \subseteq N_i, \\ 0, j \notin \Omega_p(i) \subseteq N_i, \end{cases}$$

# Methodology (2)

3. ***Long-range influence:*** consider all paths between any two elements with no cycles.

| | | **Aggregation of paths** | |
|---|---|---|---|
| | | **Sum of paths influence** | **Worst-case path influence** |
| **Path's strength** | **Multiplying direct influences** | Sum on paths | Maximum Path Influence |
| | **Minimum direct influence** | – | MinMax |

4. **Aggregating the final matrix of influence** for each borrower into a single vector that shows the total influence of each element of the system can be done with respect to the weights of each element

# LRI index based on paths

**Multiplication of direct influences:**

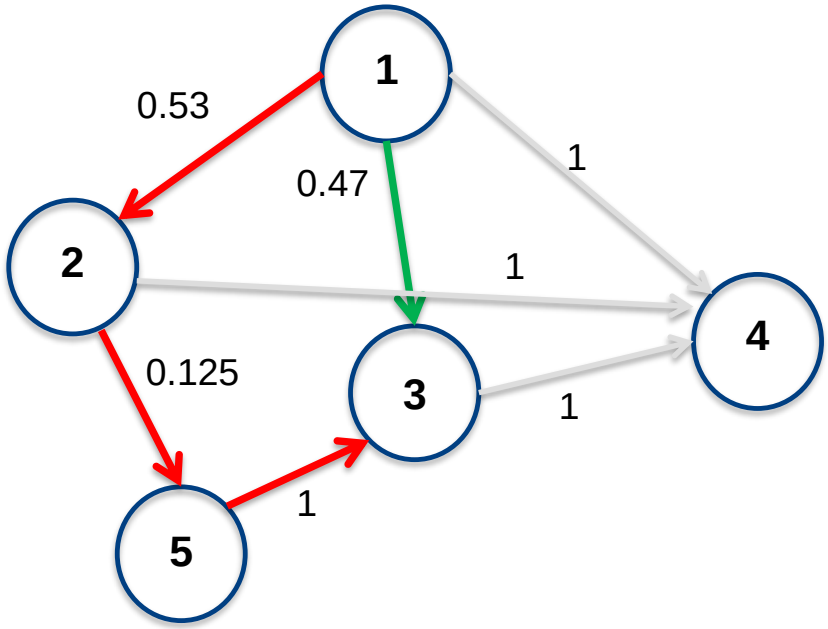
$f(P_3^{13})$=0.53*0.125*1=0.06625

$f(P_1^{13})$=0.47

**Minimal direct influence:**

$f(P_3^{13})$=min{0.53, 0.125, 1}=0.125

$f(P_1^{13})$=0.47



# Empirical application: sample

- We use Bank of International Settlements (BIS) database: BIS consolidated banking statistics (CBS) on an ultimate risk basis;
- Claims include outstanding loans and holdings of securities as well as derivative contracts and contingent facilities;
- The sample covers 22 countries that have bank foreign claims and 198 countries that have obligations for the end of 1Q2015;
- Our network covers about 94% of total foreign claims on an ultimate risk basis;
- 10% quota

# Empirical application: LRI index

| Country | Rank | | | | |
|---|---|---|---|---|---|
| | KBI | SumPaths | MaxPath | MinMax | Simul |
| **United States** | 1 | 1 | 1 | 1 | 1 |
| **Hong Kong SAR** | 4 | 2 | 2 | 2 | 2 |
| **China** | 19 | 3 | 4 | 3 | 16 |
| **United Kingdom** | 2 | 4 | 3 | 4 | 3 |
| **Singapore** | 25 | 5 | 8 | 6 | 17 |
| **Cayman Islands** | 17 | 6 | 5 | 5 | 14 |
| **Brazil** | 15 | 7 | 7 | 7 | 9 |
| **Luxembourg** | 11 | 8 | 9 | 12 | 13 |
| **Poland** | 6 | 9 | 17 | 16 | 18 |
| **Germany** | 5 | 10 | 6 | 9 | 12 |
| **Mexico** | 10 | 11 | 10 | 10 | 5 |
| **Czech Republic** | 8 | 13 | 14 | 14 | 10 |
| **Japan** | 3 | 17 | 11 | 11 | 4 |
| **Norway** | 16 | 28 | 31 | 31 | 8 |
| **Finland** | 18 | 30 | 32 | 32 | 7 |
| **Denmark** | 13 | 31 | 33 | 33 | 6 |
| **Italy** | 7 | 18 | 13 | 13 | 11 |
| **Austria** | 9 | 26 | 22 | 22 | 54 |

# Empirical application: Centrality indices

| Name | Weighted Degree | Betweenness | Closeness | PageRank | EigenVector | Copeland rule |
|---|---|---|---|---|---|---|
| **United States** | 1 | 1 | 1 | 1 | 1 | 187 |
| **United Kingdom** | 2 | 2 | 3 | 2 | 2 | 3 |
| **Germany** | 5 | 12 | 10 | 3 | 5 | 6 |
| **France** | 4 | 14 | 14 | 4 | 4 | 2 |
| **Japan** | 3 | 10 | 2 | 5 | 3 | 1 |
| **Netherlands** | 9 | 16 | 18 | 6 | 9 | 9 |
| **Cayman Islands** | 13 | 18 | 20 | 7 | 10 | 186 |
| **China** | 15 | 18 | 22 | 8 | 14 | 184 |
| **Hong Kong SAR** | 14 | 18 | 19 | 9 | 13 | 185 |
| **Italy** | 10 | 6 | 12 | 10 | 11 | 13 |
| **Spain** | 6 | 4 | 4 | 11 | 8 | 4 |
| **Canada** | 8 | 10 | 14 | 12 | 6 | 7 |
| **Australia** | 11 | 3 | 7 | 16 | 12 | 10 |
| **Switzerland** | 7 | 19 | 20 | 17 | 7 | 5 |
| **Belgium** | 17 | 5 | 5 | 24 | 21 | 174 |
| **India** | 24 | 6 | 3 | 25 | 22 | 183 |
| **Austria** | 16 | 9 | 9 | 27 | 24 | 11 |
| **Sweden** | 12 | 7 | 6 | 29 | 15 | 8 |

# LRI index vs centrality indices

Kendall $\tau$ -coefficient

| | WDeg | Clos | PageRank | EigenVec | Betw | Sim | Sum | MaxPath | MinMax |
|---|---|---|---|---|---|---|---|---|---|
| **WDeg** | - | 0,908 | 0,987 | 0,974 | 0,464 | 0,911 | 0,926 | 0,930 | 0,918 |
| **Clos** | | - | 0,898 | 0,922 | 0,483 | 0,845 | 0,869 | 0,870 | 0,843 |
| **PageRank** | | | - | 0,951 | 0,438 | 0,913 | 0,937 | 0,939 | 0,933 |
| **EigenVec** | | | | - | 0,456 | 0,869 | 0,897 | 0,897 | 0,866 |
| **Betw** | | | | | - | 0,355 | 0,344 | 0,359 | 0,353 |
| **Sim** | | | | | | - | 0,966 | 0,967 | 0,965 |
| **Sum** | | | | | | | - | 0,998 | 0,987 |
| **MaxPath** | | | | | | | | - | 0,988 |
| **MaxMin** | | | | | | | | | - |

Goodman, Kruskal $\gamma$-coefficient $\gamma = \frac{N_+ - N_-}{N_+ + N_-}$

| | WDeg | Clos | PRank | EigenVec | Betw | Sim | Sum | MaxPath | MinMax |
|---|---|---|---|---|---|---|---|---|---|
| **WDeg** | - | 0,745 | 0,903 | 0,880 | 0,378 | 0,730 | 0,767 | 0,772 | 0,743 |
| **Clos** | | - | 0,728 | 0,763 | 0,397 | 0,654 | 0,684 | 0,684 | 0,657 |
| **PRank** | | | - | 0,828 | 0,354 | 0,739 | 0,791 | 0,789 | 0,768 |
| **EigenVec** | | | | - | 0,371 | 0,673 | 0,719 | 0,719 | 0,681 |
| **Betw** | | | | | - | 0,289 | 0,278 | 0,291 | 0,285 |
| **Sim** | | | | | | - | 0,887 | 0,887 | 0,874 |
| **Sum** | | | | | | | - | 0,976 | 0,924 |
| **MaxPath** | | | | | | | | - | 0,930 |
| **MaxMin** | | | | | | | | | - |

# Results

- All three versions of LRI gives us almost similar rankings, whereas method based on simulations demonstrates some differences;

- Regional groupings for simulations (Scandinavian, Baltic countries, Australia and New Zealand);

- Rankings of LRI indices are highly related to the results of the PageRank. Other centrality measures also highly correlated with LRI (except the betweenness centrality and weighted out-degree centrality measures)

- The highest ratings were obtained for two types of countries:
  a) major players with high ratings and positive credit history;
  b) intermediary players, which have a great scale of financial activities through the creation of favorable investment conditions and positive business climate.

# Conclusions

- **Network approach can be applied to different segments of the financial system in order to characterize a systemic risk;**

- **We explore two approaches to measure systemic importance: measurement of long-range interactions' intensities based on paths, and measurement of long-range interactions' intensities based on simulations;**

- **This network model aims to help regulators identify the financial elements that are too big or too interconnected to fail during any specific crisis. The proposed methodology allows to identify countries, which at first sight do not have high level of systemic importance, but have a significant impact on the stability of the system as a whole.**

# Directions for future research

- **Dynamic analysis of key elements evolution;**
- **Differentiating of capital flows (by sectors)**

# Thank you!

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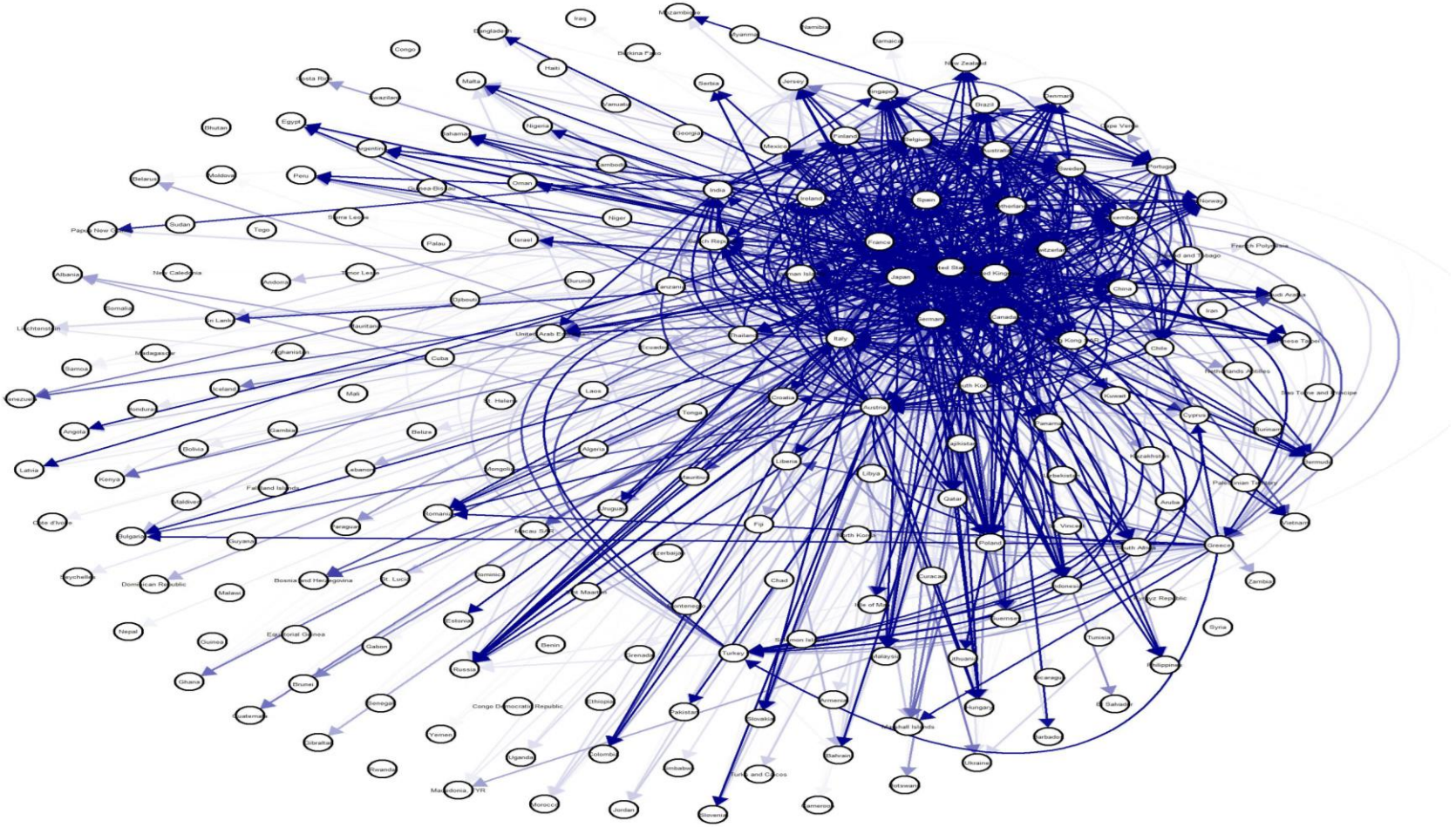
# Empirical application: network


Iraq
Bangladesh
Haiti
Malta
Jersey
Jamaica
Brazil
Egypt
Nigeria
Ghana
Mexico
Belgium
Peru
Oman
India
Ireland
Spain
Portugal
Sudan
Niger
Israel
France
Japan
China
Albania
Somalia
Cuba
Mali
Laos
Croatia
Austria
Chile
Angola
Bolivia
Kenya
Latvia
Bulgaria
Guyana
Greece
Seychelles
Nepal
Guinea
Ghana
Brunei
Senegal
Yemen
Uganda
Zimbabwe
Jordan
Slovenia
Chad
Russia
Turkey
Malaysia
Pakistan
Colombia
Bahrain
Ukraine
Belarus
Moldova
Togo
Sierra Leone
Timor-Leste
Djibouti
Sri Lanka
Mauritius
Cameroon
Belize
Lesotho
Gabon
Comoros
Suriname
Equatorial Guinea
Bosnia and Herzegovina
St. Lucia
Dominican Republic
Malawi
Estonia
Benin
Grenada
Congo, Democratic Republic
Ethiopia
Armenia
Kuwait
Cyprus
Slovakia
Libya
Qatar
Poland
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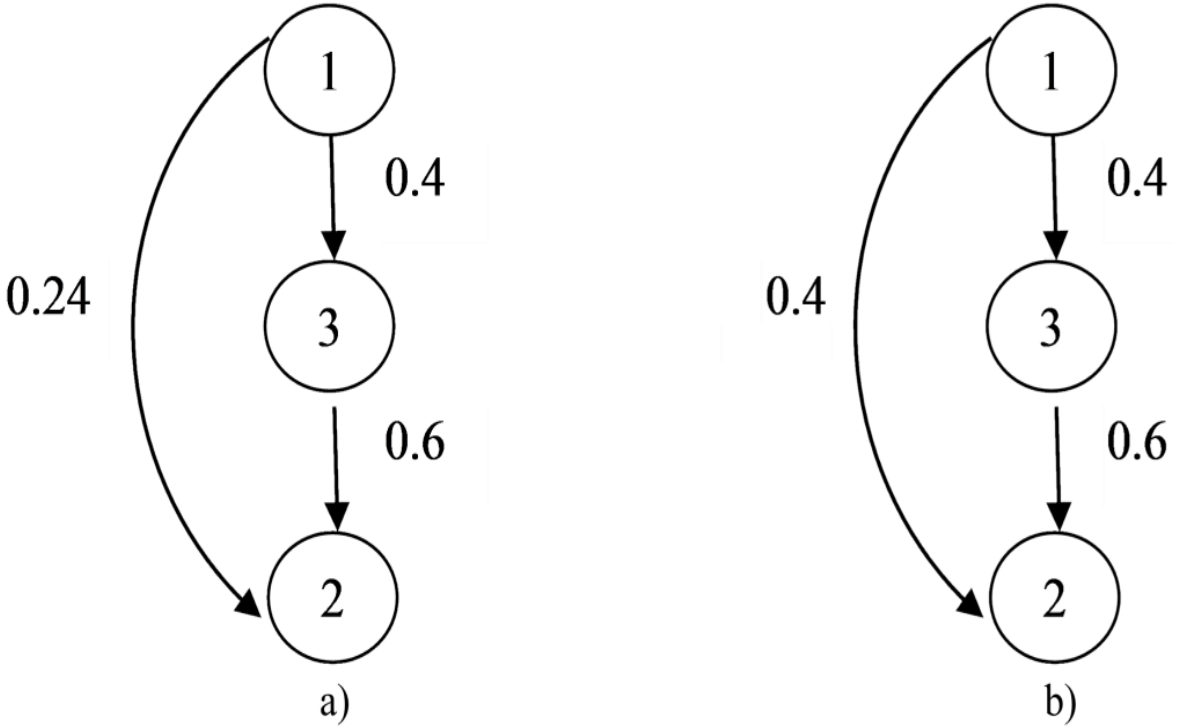
# Indirect influence: a) multiplication of direct influences and b) minimal direct influence