Financial Globalization and Financial Instability

One century of stock markets integration in a price networks perspective

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Rutgers University
September 24th, 2018

Outline

1. Introduction
   - Motivation
   - Reference Literature: financial globalization indicators and history
   - Reference Literature: financial networks
2. Data and Methodology
   - Descriptive statistics
   - Financial networks
3. Dynamics of network indicators and structure of network representations
   - Minimal spanning tree
   - Network indicators of distance and connectivity derived from the MST
   - Time series of network indicators
   - Additional insights and country specific effects
4. Concluding remarks

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Motivation

An original approach of financial integration

- Original focus on stock markets integration
- New database (national stock markets indices, 17 countries, 1885-2017, monthly data)
- Innovative method in the field of Cliometrics, borrowed from the Econophysics literature: price networks derived from price time series (vs. volume networks derived from trades in the existing Economic History literature)
- Price networks allow to calculate two types of network indicators: connectivity indicators (two nodes in a network can be connected or not) AND distance indicators (when they are connected they can be close or not)

Main contributions:

- Confirmation of the main stylized fact: "U shape" of financial globalization
- Addition to the literature: thorough analysis of network distorsions over time, country specific effects

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Reference literature (1): financial globalization indicators and history

Capital flows indicators:

- Net capital flows
- Current account balances
- Savings-Investement ("Feldstein-Horioka") correlation
- etc.

Price indicators:

- Covered interest parity
- Real interest parity
- Crossed correlations indicators [Forbes and Rigobon, 2002]
- Portfolio management models (CAPM Beta) [Bekaert and Mehl, 2017]
- etc.

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Reference literature (1): financial globalization indicators and history

"U shape" sequence of capital markets globalization [Bordo et al., 1998, Obstfeld and Taylor, 2004].

- 1st modern era of global finance: prior to WWI
- Interwar disintegration
- 2nd modern era of global finance: starting after WW2

Debate on the comparison between the 1st and 2nd eras

- level of globalization
- market segments:
  - debt/equities,
  - types of debt by lender/borrower/term/garanty,
  - types of equities by industry,
  - etc.

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Reference literature (2): financial networks

Groundbreaking papers in the field of econophysics: Mantegna [1999], Bonanno et al. [2001], Tumminello et al. [2007].

Topological graphs obtained from the price correlations matrix.

- Minimal spanning tree [Held and Karp, 1970]
- Hierarchical tree
- Network representations based on the common component of prices time series as "globalization networks" [Bastidon and Parent, 2016]

By analogy with ecosystems, changes in the structure of topological graphs depending on the environment:

- Multiple equilibria [May et al., 2008, Johnson et al., 2013]
- Economic/financial/political/regulatory/etc. shocks ?

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Reference literature (2): financial networks

No literature on price networks of equity markets with a period of study dating back to the first era: usually short/recent periods of study.

Aim of this paper:

- price networks of equity markets in historical perspective
- Time series of network indicators: innovative indicators of financial integration
- Analysis of network distorsions over time.

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Descriptive statistics

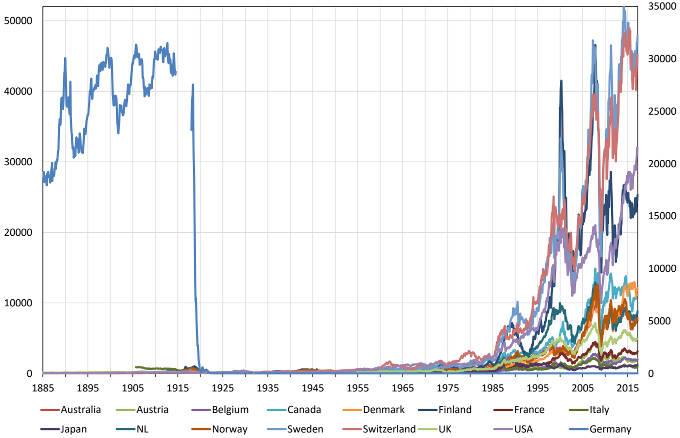

Figure 1: Equity indices in level (100 = 31/01/1922, Germany: right axis)

Descriptive statistics

Variable	Mean	Median	S.D.	Min	Max
Germany	6049,9	2,5934e-8	11152,	0,0	31514,
Australia	1328,8	239,23	2286,7	27,9	11284,
Austria	393,35	89,622	747,13	7,8	4400,4
Belgium	356,31	112,07	569,43	25,1	2807,1
Canada	1844,9	326,97	3265,7	70,8	14862,
Denmark	1251,5	163,06	2607,5	61,5	12929,
Finland	4147,7	379,65	8596,8	80,0	46547,
France	594,09	170,10	949,31	39,3	4480,1
Italy	403,80	229,24	418,99	47,9	2225,3
Japan	282,20	68,500	433,78	1,5	1879,6
NL	1569,6	170,43	2875,1	29,3	12897,
Norway	1333,3	361,27	2425,8	75,2	12593,
Spain	340,78	138,53	428,43	37,593	2300,6
Sweden	5645,4	260,46	11865,	43,0	52080,
Switzerland	5639,3	399,82	11222,	86,8	48956,
UK	1043,4	181,29	1659,2	67,9	7164,8
USA	3618,7	323,42	6712,7	51,7	32043,

Table 1: Descriptive statistics, 1885:01 - 2017:03 (not including missing values), 100 = 31/01/1922

Subperiods

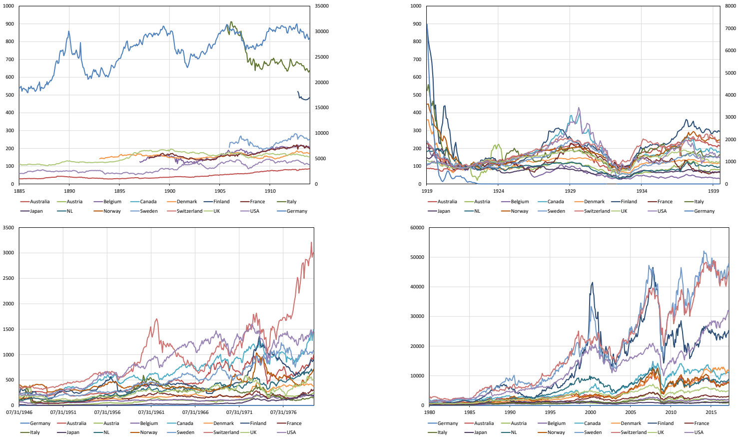

Figure 2: Equity indices in level (100 = 31/01/1922, (a) 1st era, (b) interwar, (c) early 2nd era, (d) late 2nd era. Germany: right axis)

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Price networks, volume networks

In the field of economics: volume networks (international trade, interbank markets, foreign exchange markets, etc.)

- Nodes: firms, countries, marketplaces, etc.
- Edges:
  - Existence of a commercial/financial/etc. relationship between two nodes
  - Directly given by the data
- Volume networks are a specific representation of the dataset

In the field of econophysics: volume (most often interbank markets) AND price networks (most often stock markets)

- Nodes: banks, equities, etc.
- Edges:
  - Volume networks: existence of interbank loans between two nodes
  - Price networks: derived from price time series
- Price networks are representations of the underlying network model (obtained by topological algorithms)

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From the dataset to price networks

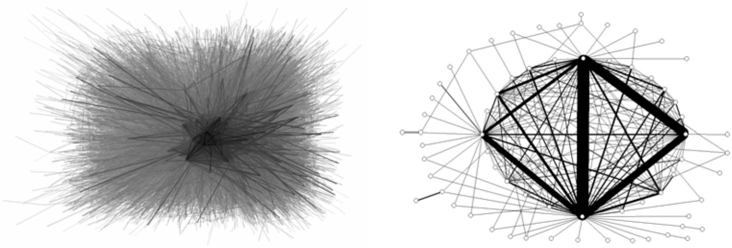

Figure 3: Graph (left) and subgraph (right) [Soramäki et al., 2007]

Topological representations of price networks of stock markets:

- Nodes: assets (individual stocks, stock markets country indices, etc.)
- Edges: distances derived from correlations matrices of price time series
- Subgraphs: economically meaningfull edges (Mantegna, 1998)

Correlations and distances

Methodology of the Minimal spanning tree [Mantegna, 1999]:

1. Correlations matrix of log differences of price data:

$$\rho_{ij} = \frac{\mathrm{Cov}\left(p_i, p_j\right)}{\sigma_{p_i} \cdot \sigma_{p_j}} \tag{1}$$

2. Distance matrix (Euclidean metric) derived from the correlations matrix:

$$d\left(i,j\right) = \sqrt{2(1-\rho_{i,j})} \tag{2}$$

$$\begin{gathered} d\left(i,j\right) = 0 \text{ if and only if } i = j \\ d\left(i,j\right) = d\left(j,i\right) \\ d\left(i,j\right) \leq d\left(i,k\right) + d\left(k,j\right) \end{gathered}$$

3. (Unique) minimal spanning tree: connected, cycleless, minimum weight, hierarchical tree of identical branching.

Complete network

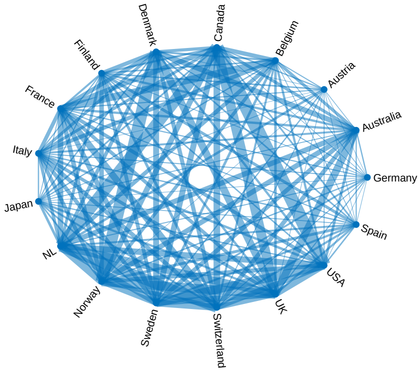

Figure 4: Graph of the full distances matrix, edge widths representing the distances between pairs of nodes, Interwar

Minimal spanning tree

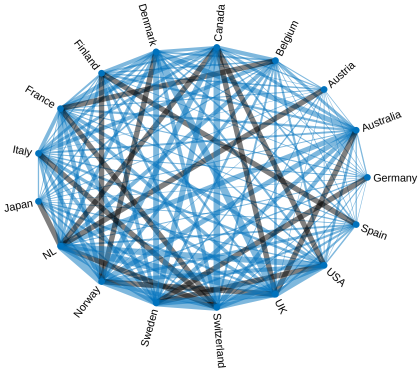

Figure 5: Minimal spanning tree highlighted as a subgraph of the complete network, Interwar

Minimal spanning tree

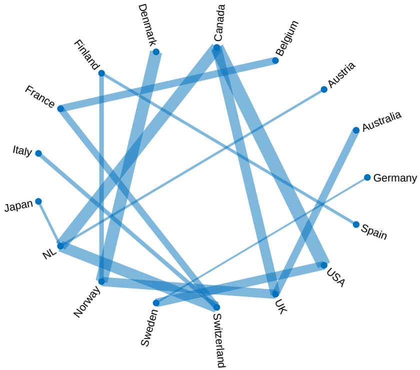

Figure 6: Minimal spanning tree, edge widths representing the distances between pairs of nodes, Interwar

Minimal spanning tree

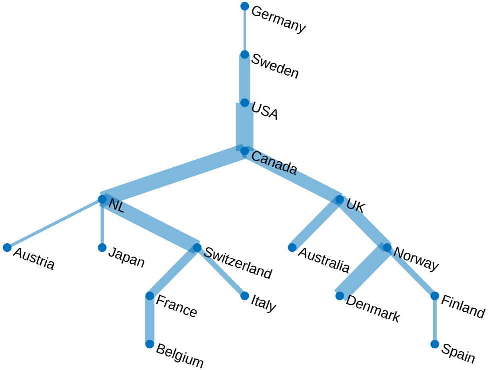

Figure 7: Minimal spanning tree, hierarchical representation, edge widths representing the distances between pairs of nodes, Interwar

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Network indicators

Original indicators of financial integration in this paper: network indicators (distance/connectivity).

3 distance indicators:

- Average distance to the nearest neighbors
- Average path length
- Eccentricity
- ... expected to decrease when integration rises

2 connectivity indicators:

- Average degree (number of neighbors) of the nearest neighbors
- Standard deviation of the degree of the nodes
- ... expected to increase when integration increases

Time series of network indicators [Abry et al., 2018].

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Average distance to the nearest neighbors

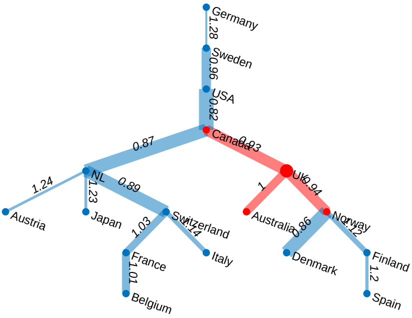

Figure 8: Minimal spanning tree, interwar, distances on the edges, nearest neighbors of the UK

Average distance to the nearest neighbors:

- Measure of distances within the nearest neighborhood
- "Local" integration
- ... expected to decrease when integration to the close neighborhood rises

Average path lenght

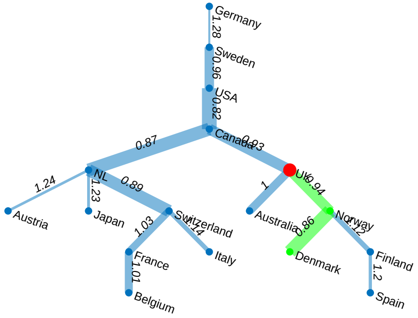

Figure 9: Minimal spanning tree, interwar, path from the UK to Denmark

Average path length:

- All possible paths from a node to each of the other nodes within the network
- "Global" integration.
- ... expected to decrease when integration to the rest of the world rises

Eccentricity

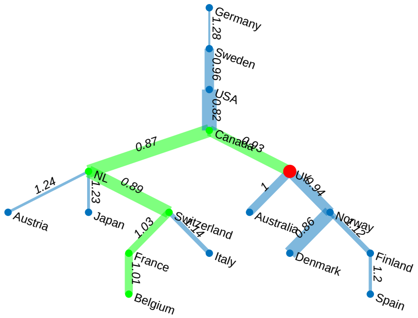

Figure 10: Minimal spanning tree, interwar, eccentricity of the UK corresponding to the path from the UK to Belgium

Eccentricity:

- Eccentricity: longest path lenght from a given node
- Convergence.
- ... expected to decrease when integration to the furthest part of the world rises

Average degree of the nearest neighbors

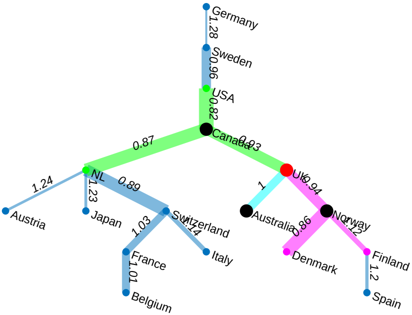

Figure 11: Minimal spanning tree, interwar, degrees of the nearest neighbors (NN) of the UK. In green: NN of Canada (3), in light blue: NN of Australia (1), in pink: NN of Norway (3)

Average degree of the nearest neighbors:

- Degree of the nearest neighbors: number of edges of the nearest neighbors.
- ... expected to increase when integration increases

Standard deviation of the degree of the nodes

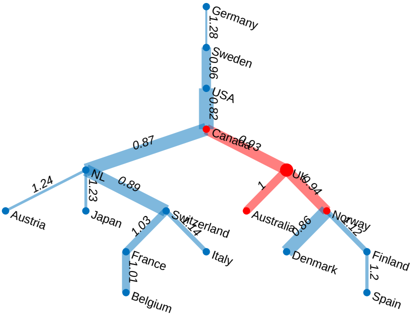

Figure 12: Minimal spanning tree, interwar, degree of the UK

Standard deviation of the degree of the nodes:

- Standard deviation of the number of nearest neighbors
- ... expected to increase when integration increases

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Network indicators

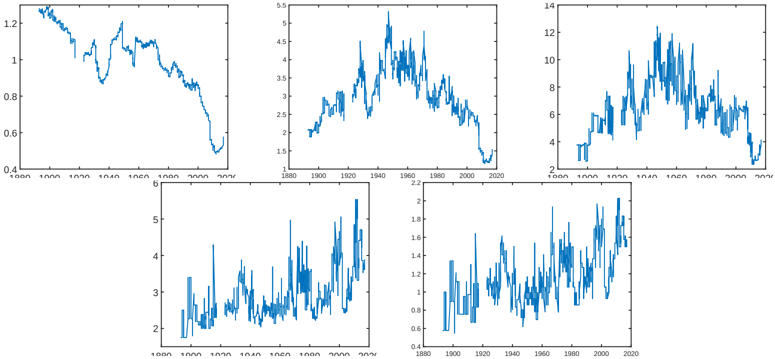

Figure 13: Network indicators, 1906:01 - 2017:03. (a) to (c): distance measures, (a) distances to the nearest neighbors, (b) average pathes lenghts, (c) eccentricity; (d) and (e): connectivity measures: (d) average nearest neighbors degree, (e) standard deviation of degrees

Network indicators

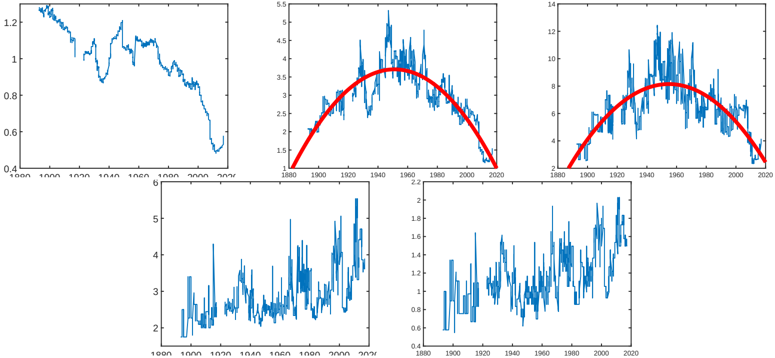

Figure 14: Network indicators, 1906:01 - 2017:03. (a) to (c): distance measures, (a) distances to the nearest neighbors, (b) average pathes lenghts, (c) eccentricity; (d) and (e): connectivity measures: (d) average nearest neighbors degree, (e) standard deviation of degrees

A U-shape of path lenght measures (average path lenghts, eccentricity): inverted U-shape since increasing distances mean decreasing integration.

Network indicators, 1st era

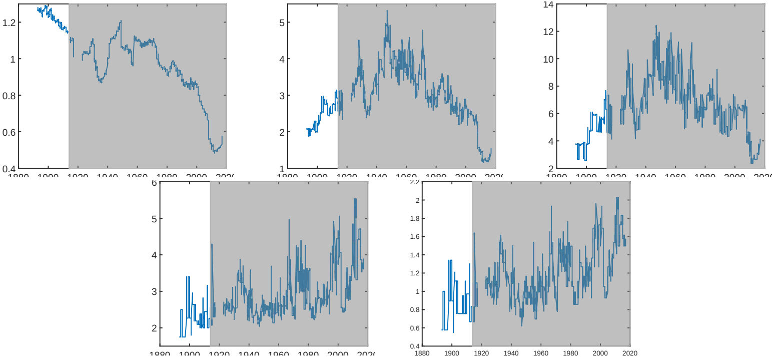

Figure 15: Network indicators, 1906:01 - 2017:03. (a) to (c): distance measures, (a) distances to the nearest neighbors, (b) average pathes lenghts, (c) eccentricity; (d) and (e): connectivity measures: (d) average nearest neighbors degree, (e) standard deviation of degrees

Decreasing local distance measures, increasing global distance measures: integration to the close neighborhood in the 1st era?

Network indicators, interwar

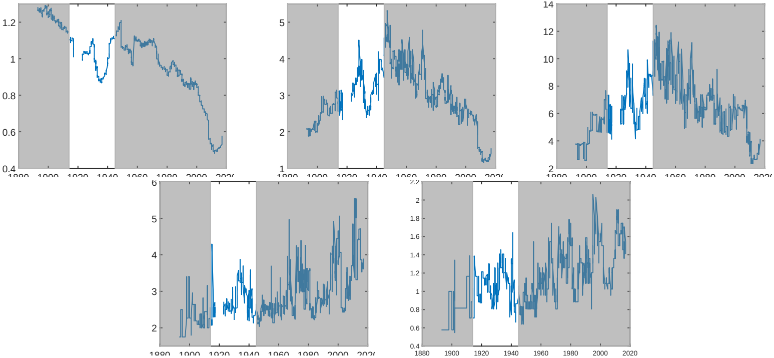

Figure 16: Network indicators, 1906:01 - 2017:03. (a) to (c): distance measures, (a) distances to the nearest neighbors, (b) average pathes lenghts, (c) eccentricity; (d) and (e): connectivity measures: (d) average nearest neighbors degree, (e) standard deviation of degrees

Disintegration but not during the post 1929: decreasing distances, increasing connectivity.

Network indicators, early 2nd era

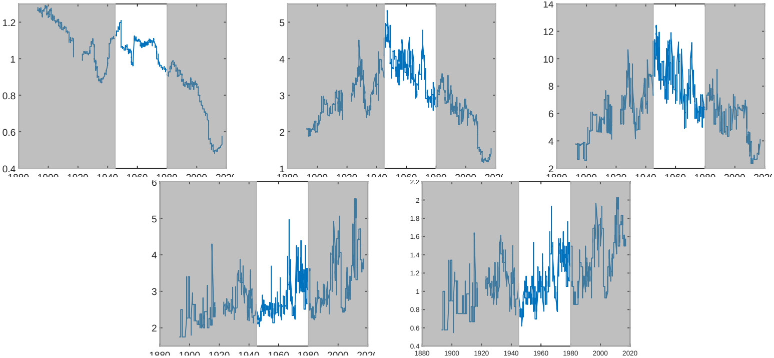

Figure 17: Network indicators, 1906:01 - 2017:03. (a) to (c): distance measures, (a) distances to the nearest neighbors, (b) average pathes lenghts, (c) eccentricity; (d) and (e): connectivity measures: (d) average nearest neighbors degree, (e) standard deviation of degrees

Decreasing global distance measures for the 1 st time: beginning of a truly global integration?

Network indicators, late 2nd era

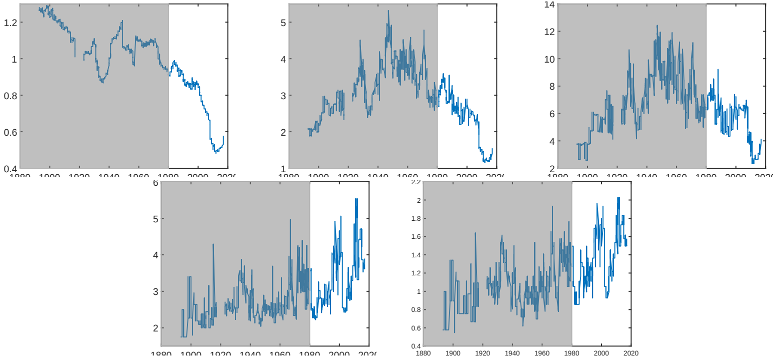

Figure 18: Network indicators, 1906:01 - 2017:03. (a) to (c): distance measures, (a) distances to the nearest neighbors, (b) average pathes lenghts, (c) eccentricity; (d) and (e): connectivity measures: (d) average nearest neighbors degree, (e) standard deviation of degrees

Unprecedented level of all distance and connectivity indicators, unprecedented volatility of connectivity.

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Minimal spanning tree, hierarchical tree

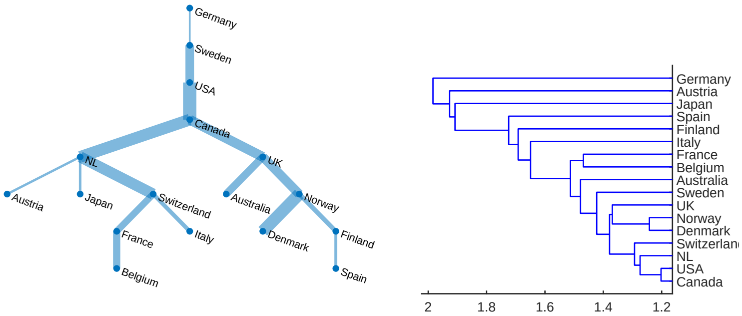

Figure 19: Network representations, interwar. (a) Minimal spanning tree representing the structure of the network, (b) Hierarchical tree of identical branching representing the hierarchy of the distances by which the nodes are connected to the network

Hierarchical trees

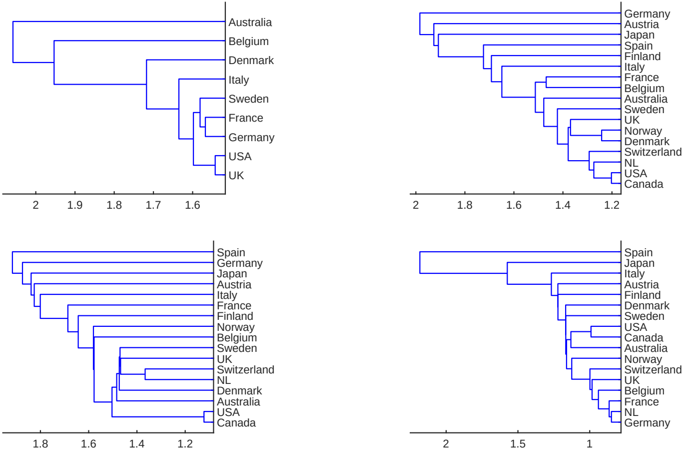

Figure 20: Hierarchical trees, (a) 1st era, (b) interwar, (c) early 2nd era, (d) late 2nd era, hierarchy of the distances by which the nodes are connected to the network

Distance matrices

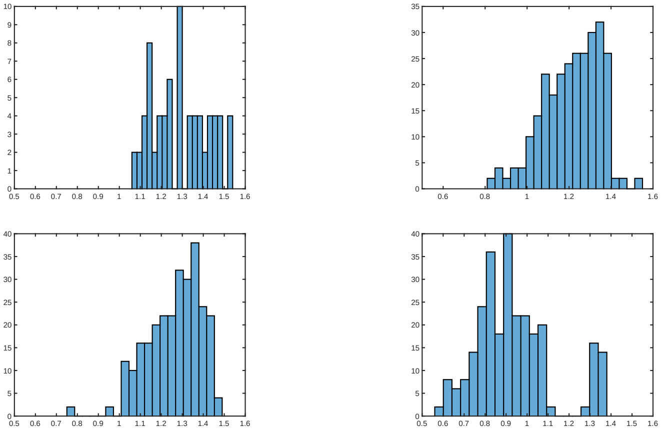

Figure 21: Histograms of distance matrices, (a) 1st era, (b) interwar, (c) early 2nd era, (d) late 2nd era, increasing integration corresponding to a translation to the left and a less negatively skewed distribution

Concluding remarks

Price networks corroborates the U shape of globalization in network representations

- Original result: enhanced integration in the aftermath of 1929
- Strong comparability of the effects of the Great Depression (1929) and the Great Recession (2008) on equity markets networks: enhanced integration
- Global U shape with country/regions specific dynamics: continental Europe, Germany, Japan, etc.

World equity markets in the late 2nd era are both more integrated and more unstable than ever (1st era, early 2nd era)

- Unprecedented decrease in local (nearest neighbours) and global (path lengths) distance measures: truly global integration
- Unprecedented increase (and increasing instability) in connectivity measures: more connected, less stable.

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