A topology of world equity markets, 1960-2015

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Topological representations and financial integration

World equity markets in the long run, using the literature on topological representations of assets prices (*Mantegna,* 1998; *Bonanno et al.*, 2000; *Tumminello et al.*, 2008):

- 1st contribution: integration of world capital markets as complex systems
- 2nd contribution: historical approach over 5 decades

Usual measures of capital markets integration (*Obstfeld* and *Taylor*, 2004):

- ratios of stocks of foreign investment or foreign assets to GDP
- ratio of the level of domestic investment to domestic savings (*Feldstein* and *Horioka*, 1980)
- co-evolution of domestic and foreign interests rates
- *etc*.

Increasing integration of capital markets since 1945, limited to the *intensive margins*:

- Lucas Paradox (*Lucas*, 1990): developing economies of the post-colonial era characterised by very low flows of international capital
- peculiar dynamics of foreign direct investment during the 2000s

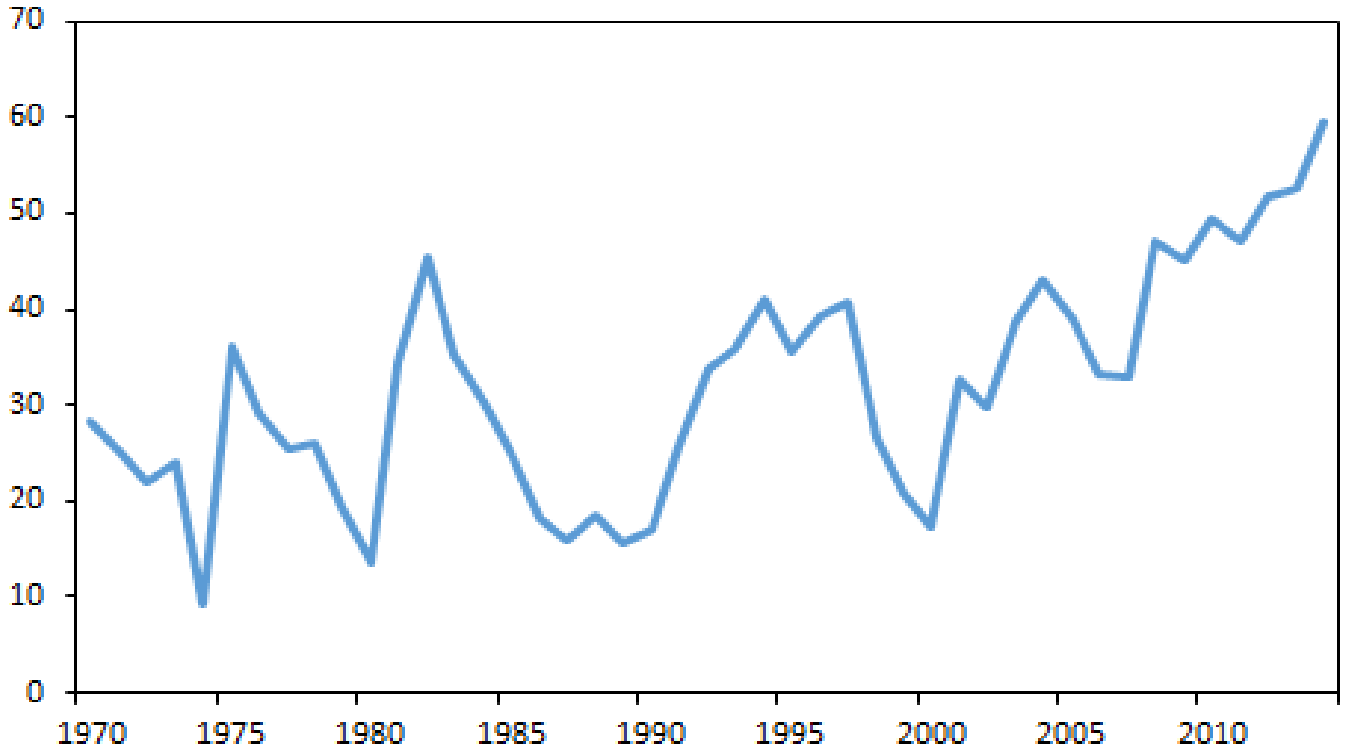

Figure 1: FDI flows to emerging and developing countries
% of the world total, source : UN

Contents

Price series

Database: FRED
Indices: 32 countries (last subperiod)
5 sub-periods: 1960s, 1970s, 1980s, 1990s, 2000-2015

- Different break dates (*Bekaert et al.*, 2002) for different countries
- Price series: peculiarity of the 1980s and 1990s

	Mean	Median	Minimum	Maximum	Standart dev.
1960s	1,30E+02	1,16E+02	6,81E+01	4,17E+02	4,44E+01
1970s	1,20E+02	1,03E+02	3,87E+01	1,10E+03	7,59E+01
1980s	2,94E+03	1,94E+02	3,58E+01	1,71E+05	1,54E+04
1990s	8,30E+07	1,23E+02	3,48E+01	7,82E+09	6,10E+08
2000-2015	1,78E+02	1,37E+02	1,02E+01	9,69E+02	1,42E+02

(observations 1950/01 - 2014/12, base 100 at the beginning of each sub-period)

Table 1: Descriptive statistics by sub-periods

Contents

Large economic / financial networks

Topological approach of complex systems:

- Network representations starting from correlation matrices
- Networks: nodes, edges (distances)

Field of finance:

- Complete networks (e.g. equity markets…): n^2 edges
- Large incomplete networks (e.g. interbank markets…): $<n^2$ edges but large
- Need to isolate the economically meaningfull edges

Minimal spanning tree (MST):

- (Unique) subgraph of a given network
- Subdominant ultrametric

Hierarchical tree (HT):

- Classification
- HT obtained by the *single linkage* or *nearest neighbor* method: same branches as the MST
- Complementarity of the MST and HT

From correlations to the MST and HT

Correlations matrices of log differences of monthly index price data.
Correlation coefficient of variables *i* and *j* :

$$\rho_{ij} = \frac{\mathrm{Cov}\left(IDV_i, IDV_j\right)}{\sigma_{IDV_i}, \sigma_{IDV_j}}$$

Distance matrices: $d\left(i,j\right) = 1 - \rho_{ij}^2$ satisfies the axioms of an Euclidian metric:

1. $d\left(i,j\right) = 0$ if and only if $i = j$
2. $d\left(i,j\right) = d\left(j,i\right)$
3. $d\left(i,j\right) \leq d\left(i,k\right) + d\left(k,j\right)$

Subdominant ultrametric of the distance matrix: MST (Kruskal's algorithm), HT (nearest neighbor method):

$$d\left(i,j\right) \leq \sup\left(d\left(i,k\right), d\left(k,j\right)\right)$$

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Topology, 1960s

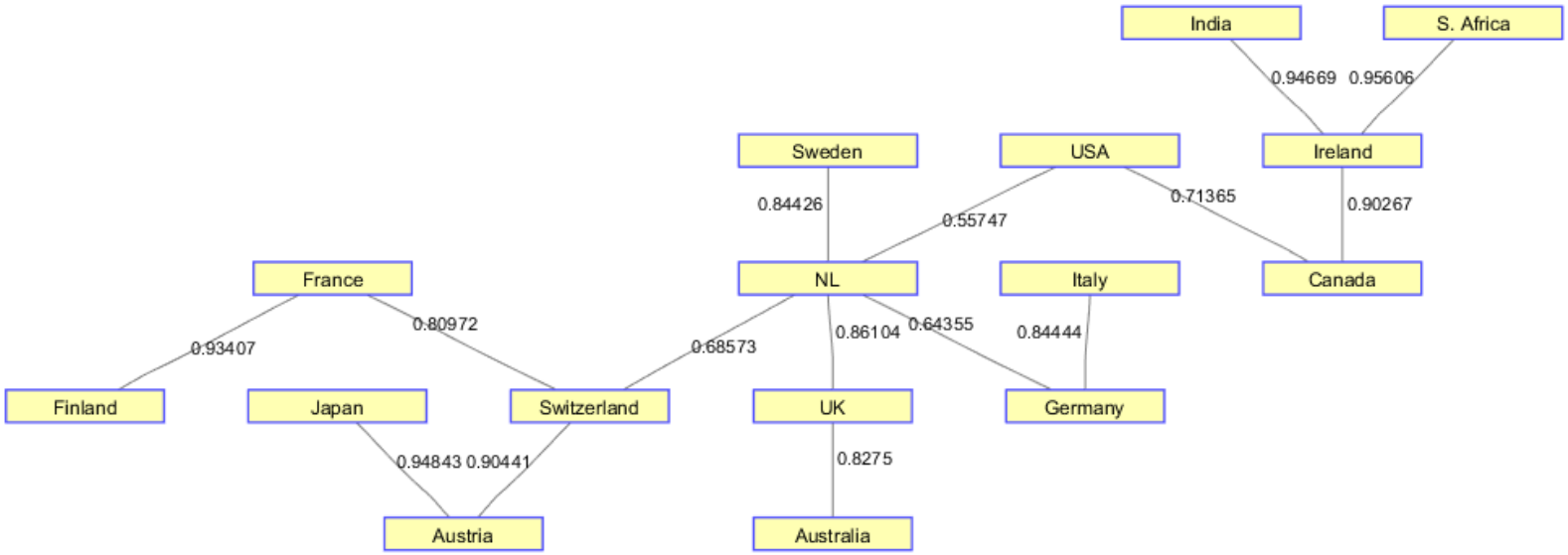

Figure 2a: Minimal spanning tree, 1960s

MST:
- Historical logic (UK and former British colonies)
- Geographical logic (Continental Europe)
  - Central place of NL in the Continental Europe subtree (all sub-periods)

HT:
- Narrow group of highly integrated markets (in order of increasing distances, Netherlands, USA, Germany, Switzerland and Canada)

Topology, 1960s

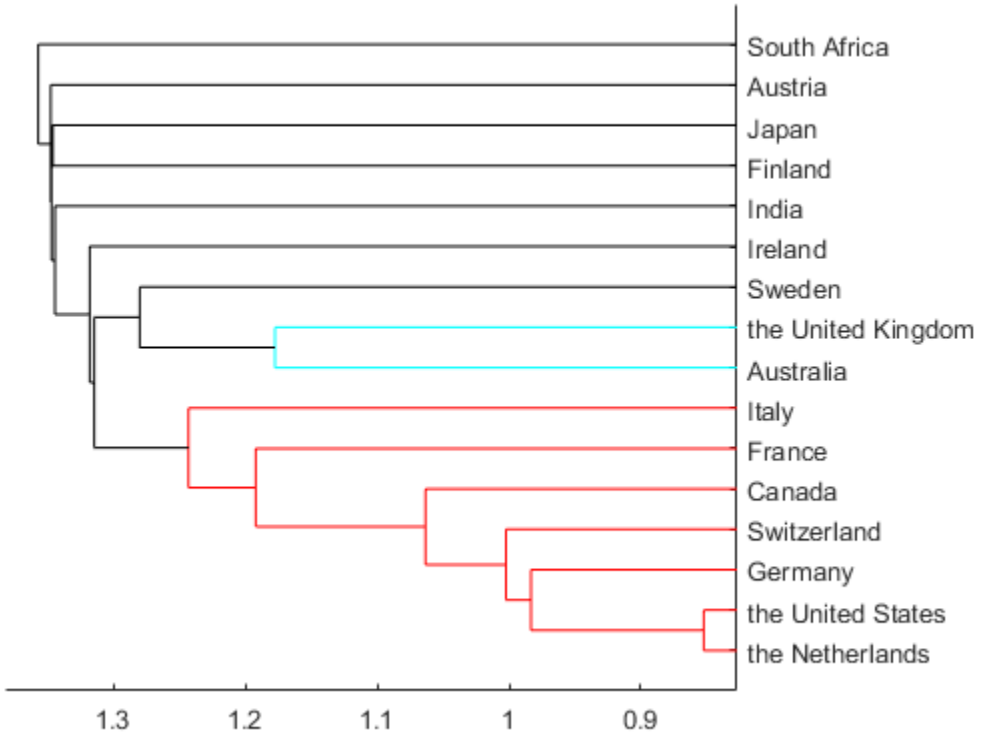

Figure 2b: Hierarchical tree, 1960s

Topology, 1970s

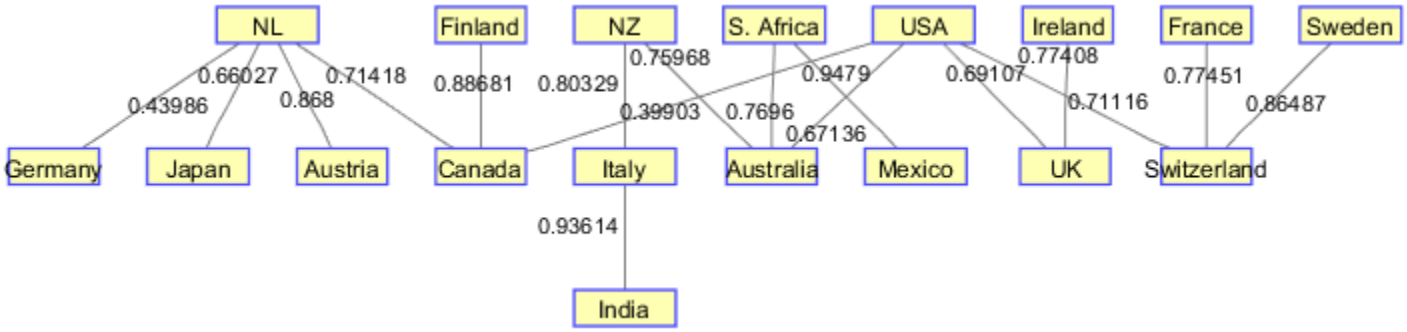

Figure 3a: Minimal spanning tree, 1970s

MST:

- 2 nodes (NL, USA) associated with an atypically large number of edges
- No obvious historical or geographical logic in the composition of the associated sub-trees
- Atypical proximity of two pairs of indices: Netherlands - Germany and especially USA - Canada

HT:

- Confirms the atypical proximity of Netherlands - Germany and USA - Canada

Topology, 1970s

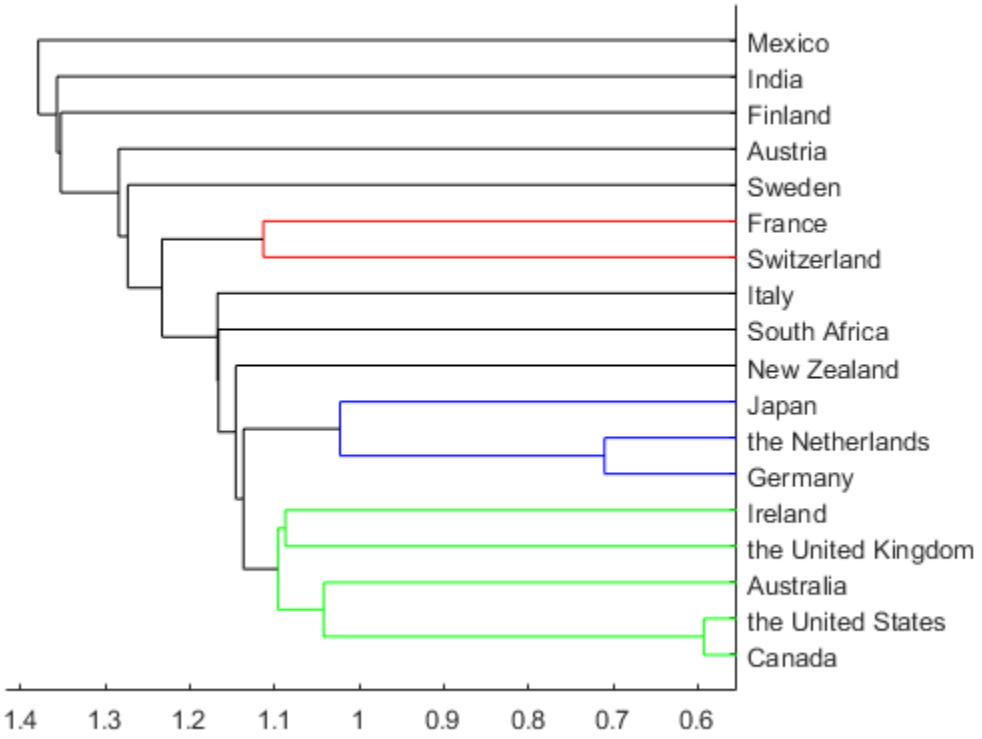

Figure 3b: Hierarchical tree, 1970s

Topology, 1980s

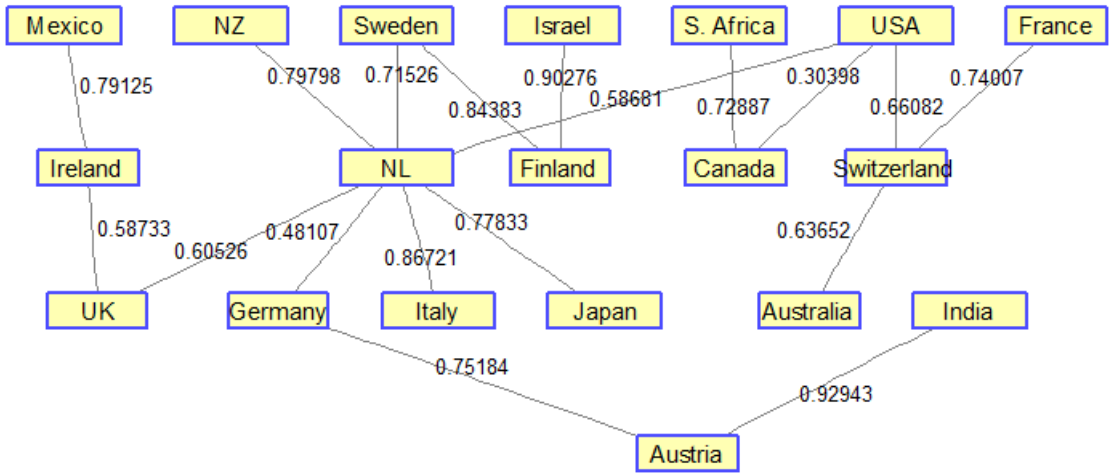

Figure 4a: Minimal spanning tree, 1980s

MST:
Roughly similar to the 1970s:

- 2 nodes (NL, USA) associated with an atypically large number of edges (4 and 4 in the 1970s, 6 and 3 in the 1980s)
- Atypical proximity of Netherlands - Germany and especially USA - Canada, confirmed by the HT

Topology, 1980s

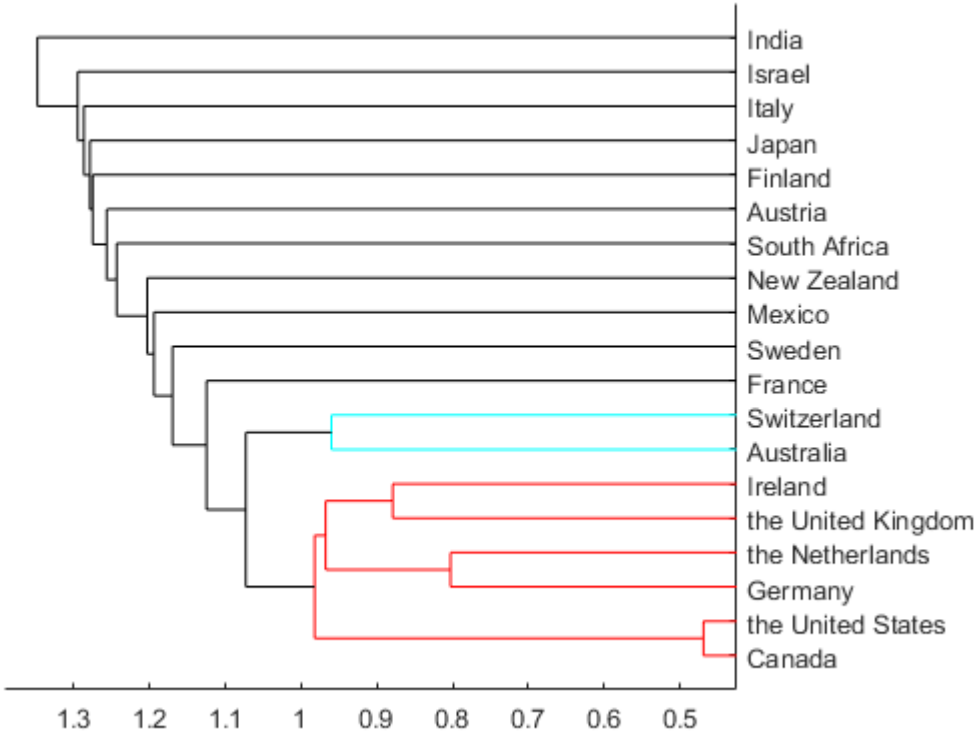

Figure 4b: Hierarchical tree, 1980s

Topology, 1990s

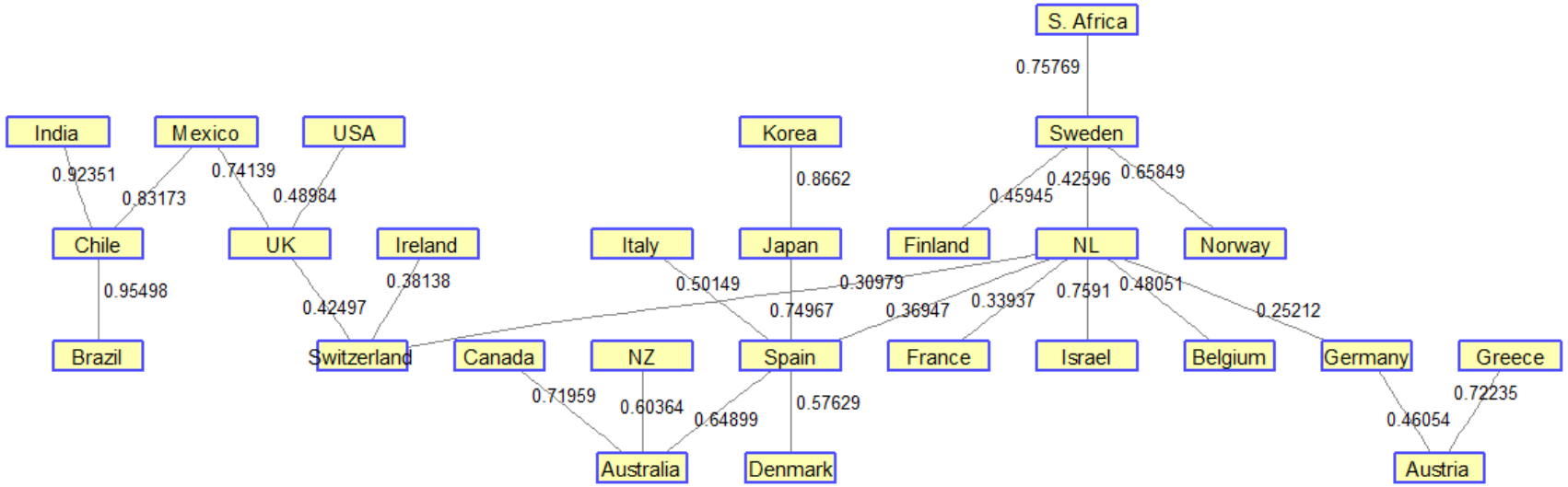

Figure 5a: Minimal spanning tree, 1990s

MST:

- Peculiar topological status of NL (7 edges, lowest distances of the sample)

HT:

3 groups:

- Highly integrated advanced economies
- Intermediately integrated advanced economies
- Less integrated emerging economies (unchanged)

Topology, 1990s

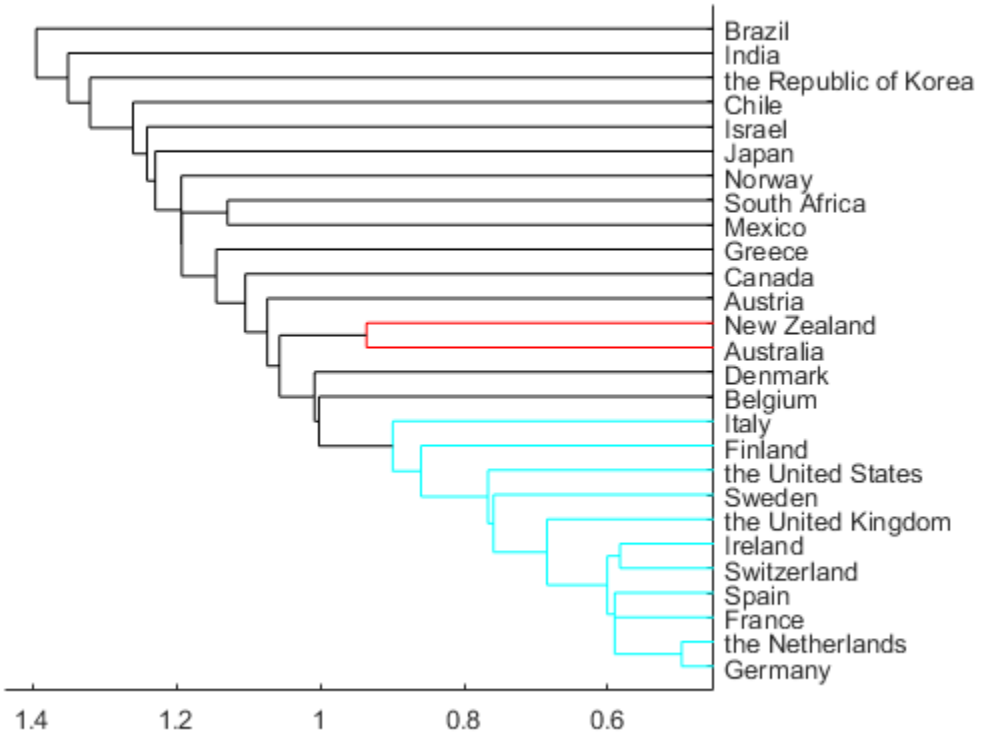

Figure 5b: Hierarchical tree, 1990s

Topology, 2000-2015

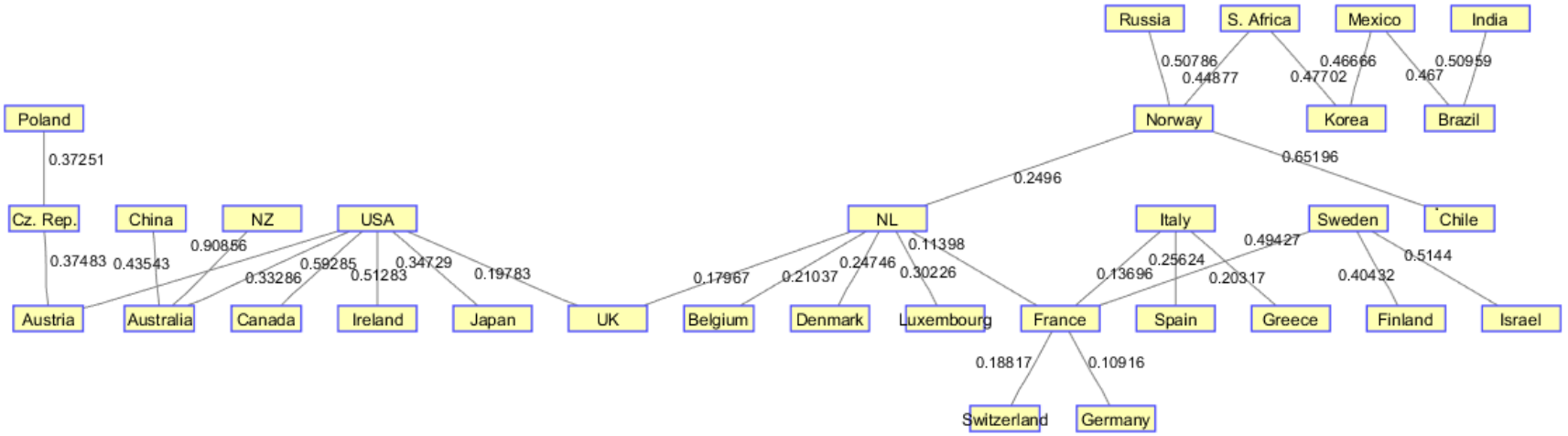

Figure 6: Minimal spanning tree, 2000-2015

MST:
- Organised around 2 nodes (NL and USA), linked by the UK
- Shortest distances of the sample in the corresponding sub-trees

HT:
- New cluster of emerging economies with intermediate degrees of integration
- Less integrated economies: both emerging (Israel, Russia, Chile, China) and advanced economies (Japan, Greece, New Zealand, Canada)
- Integration at the extensive margins in progress ?

Topology, 2000-2015

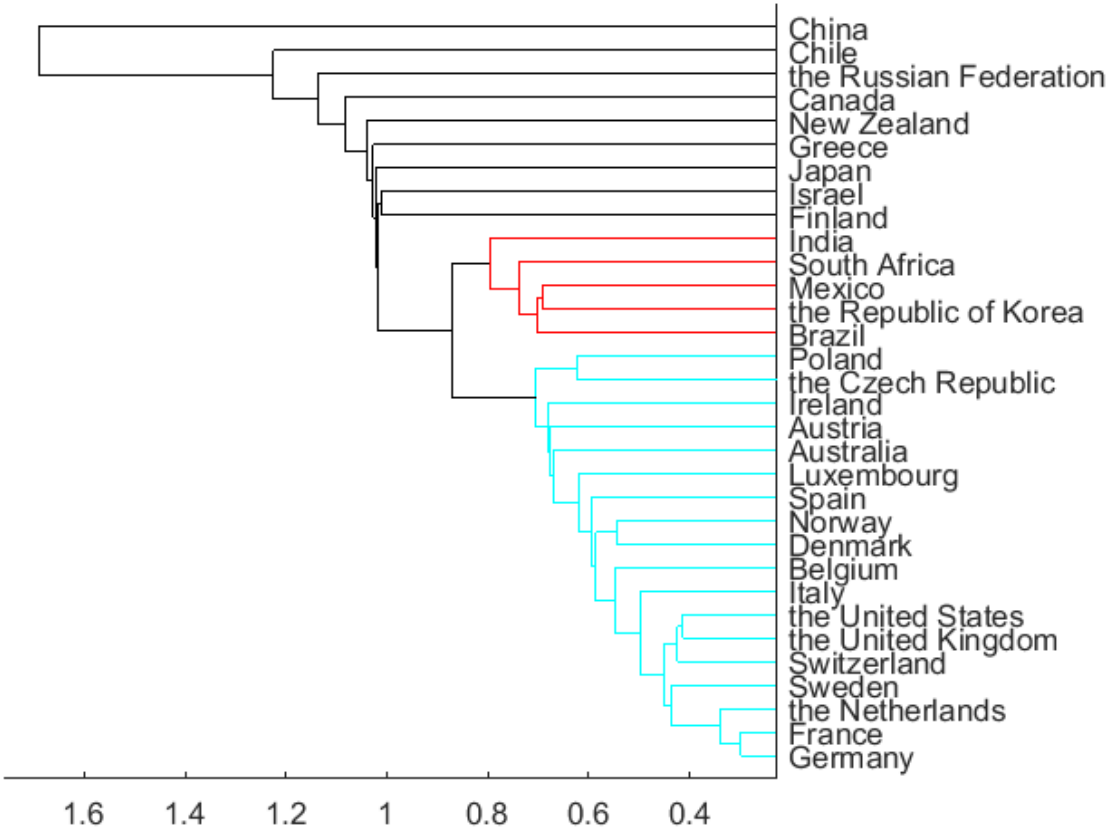

Figure 6b: Hierarchical tree, 2000-2015

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Histograms of distances matrices

Fig 6a: Distances matrix, 1990s

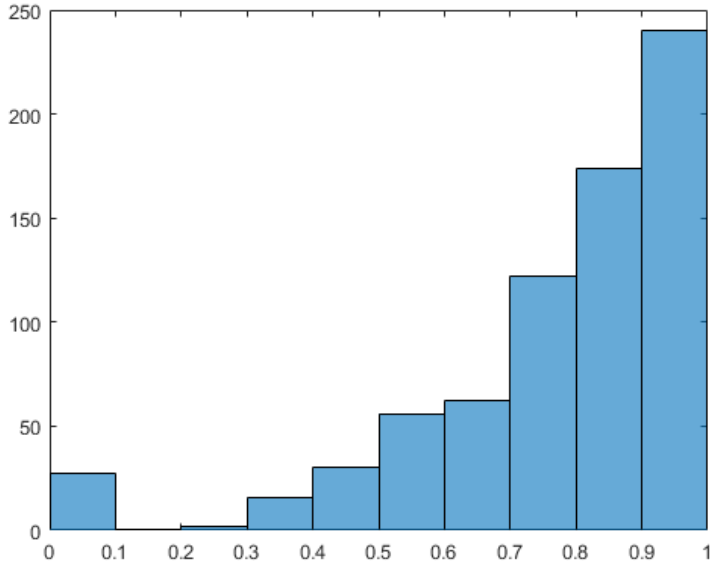
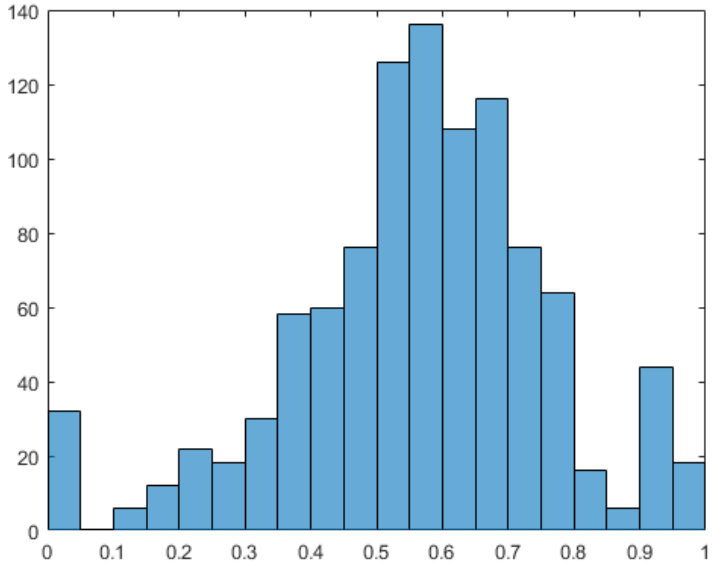


Fig 6b: Distances matrix, 2000-2015



Network statistics

Fig 7a: Average degrees, average nearest neighbour degree

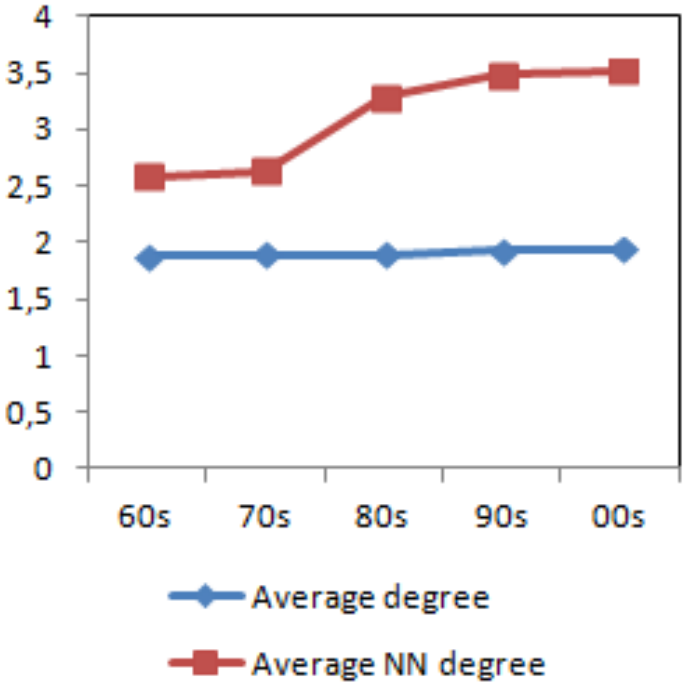
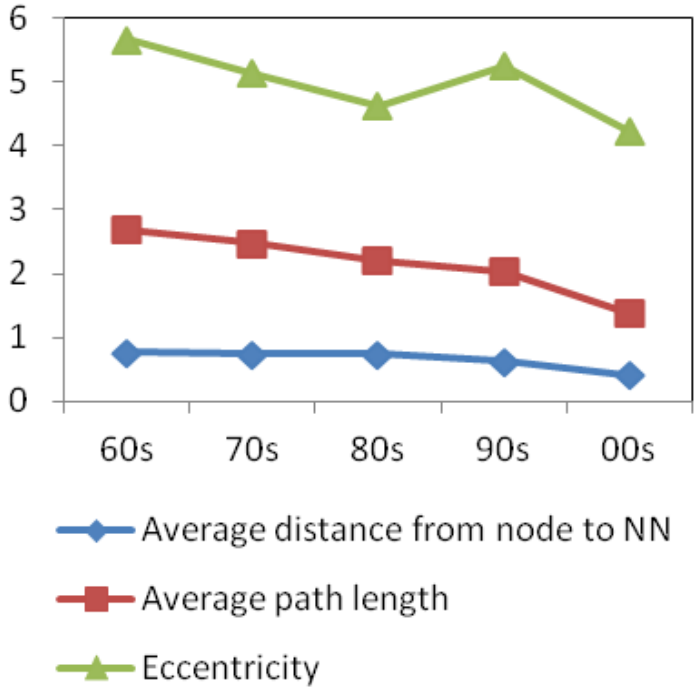


Fig 7b: Average strength, average path length, excentricity



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Main results

1. Lateness of the appearance in these topological representations of truly global markets, *i.e.* tripolar and characterised by a predominance of intermediate distances.

2. The USA acquire only at a late stage (in the 2000s) the dominant position which is expected (structure of trees, distances)

3. The only geographical or historical persistent logic over the sub-periods is the topological proximity of the equity markets of continental Europe.

4. Emerging economies in the 2000s split into two sub-groups.
   - 1st group: intermediate degree of integration
   - 2nd group: weakly integrated.

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Research perspectives

1. The overall results justify the choice of the methodology: economically meaningfull topological representations derived from long term series of equity markets indices.

2. A research perspective could be to build topological representations iteratively, in order to determine the periods as defined by the dates that generate significantly positive breakdown tests on the overall topological characteristics.