Scale in World City Networks

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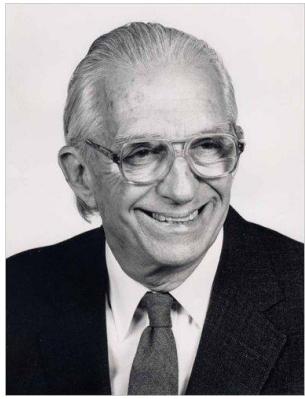
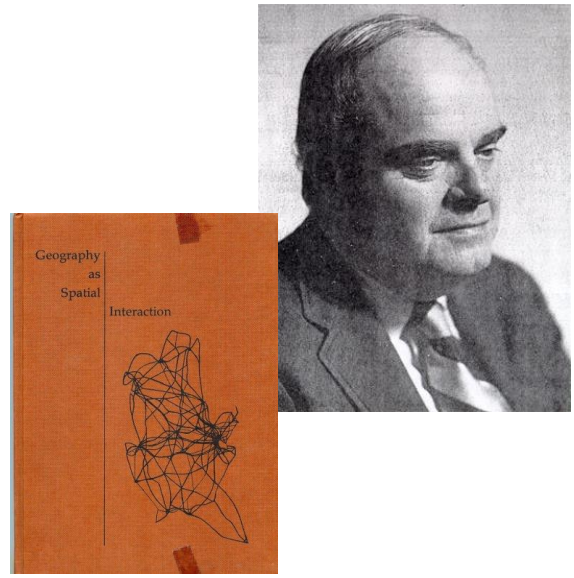
Introduction: Regional Science

- The science of the region
- The region is a geographic territory
  - "…is not merely an arbitrarily demarcated area; rather it is an area that is meaningful because of one or more problems associated with it which we as regional scientists want to examine and help solve" (Isard, 1975)
- The region as a construct
  - "Each region is supported, and in a sense defined, by a distinctive socioeconomic organization that regulates its workings and its dynamics" Thill, 2017)

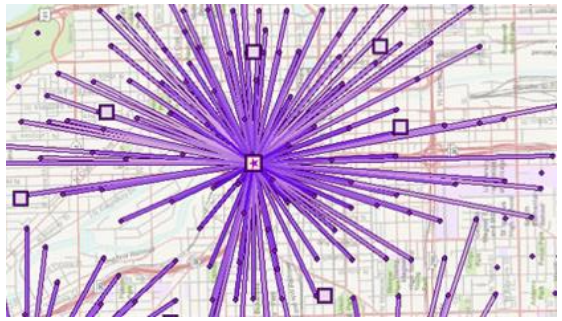


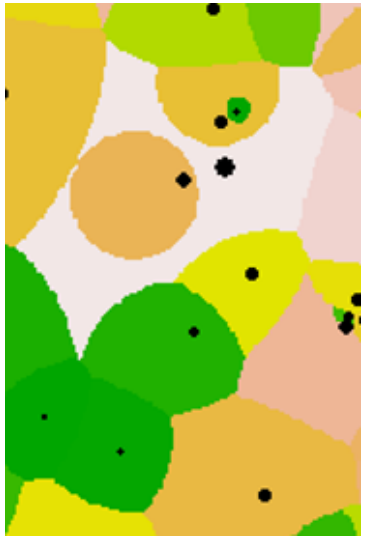
Introduction: Regional Science

- Functional regions or nodal regions
  - Functional relationships are shared within this space
  - Ullman's "Geography as Spatial Interaction"



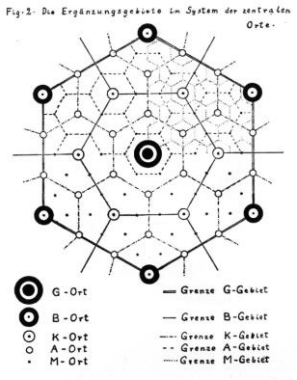
  - Hinterlands, market areas, etc



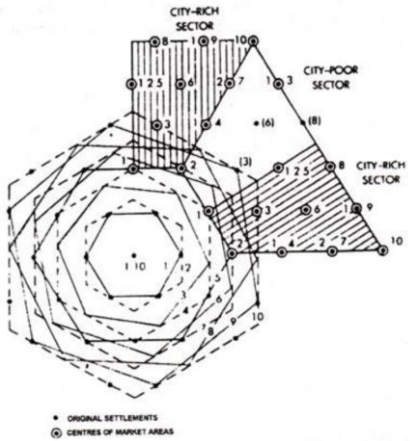


Introduction: Regional Science

- Functional regions or nodal regions
  - Christallerian central place system



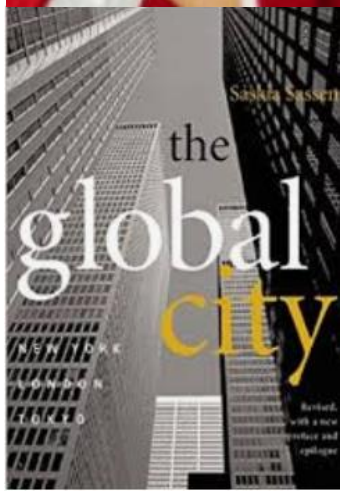
  - Losch economic landscapes



  - Cohesion between node (city) and hinterland
    - Agglomeration and hierarchy
  - Source of spatial organization

World / Global Cities

- Cities that are primary nodes in the global economic network
  - Agents of globalization
- Global cities are the focal points of people, business, culture, politics, and conflict on a global scale
- Sassen (1991): "Global City"
  - Thick flows of financial services, goods, passengers
  - Relational network embedded in geographic space
  - Role of MNC and advanced producer services (APC)
  - Standing more defined by inter-city relations that by relations with geographic hinterland (central place theory)
  - Depicts how cities are plugged into the global economy
- Castells' (1996) "network society"

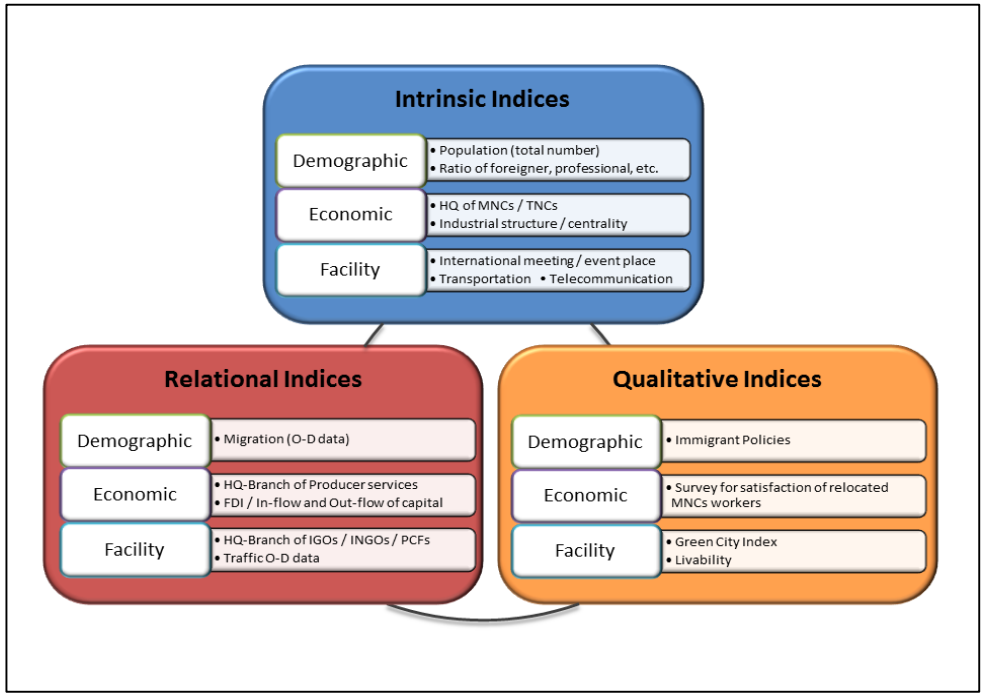


World City Research

- World City Network (WCN): a collection of city nodes and a set of links between them depicting the existence or strength of their functional connections
- Three scales (network science):
  - Microscale (local)
  - **Mesoscale (intermediate)**
  - Macroscale (global)

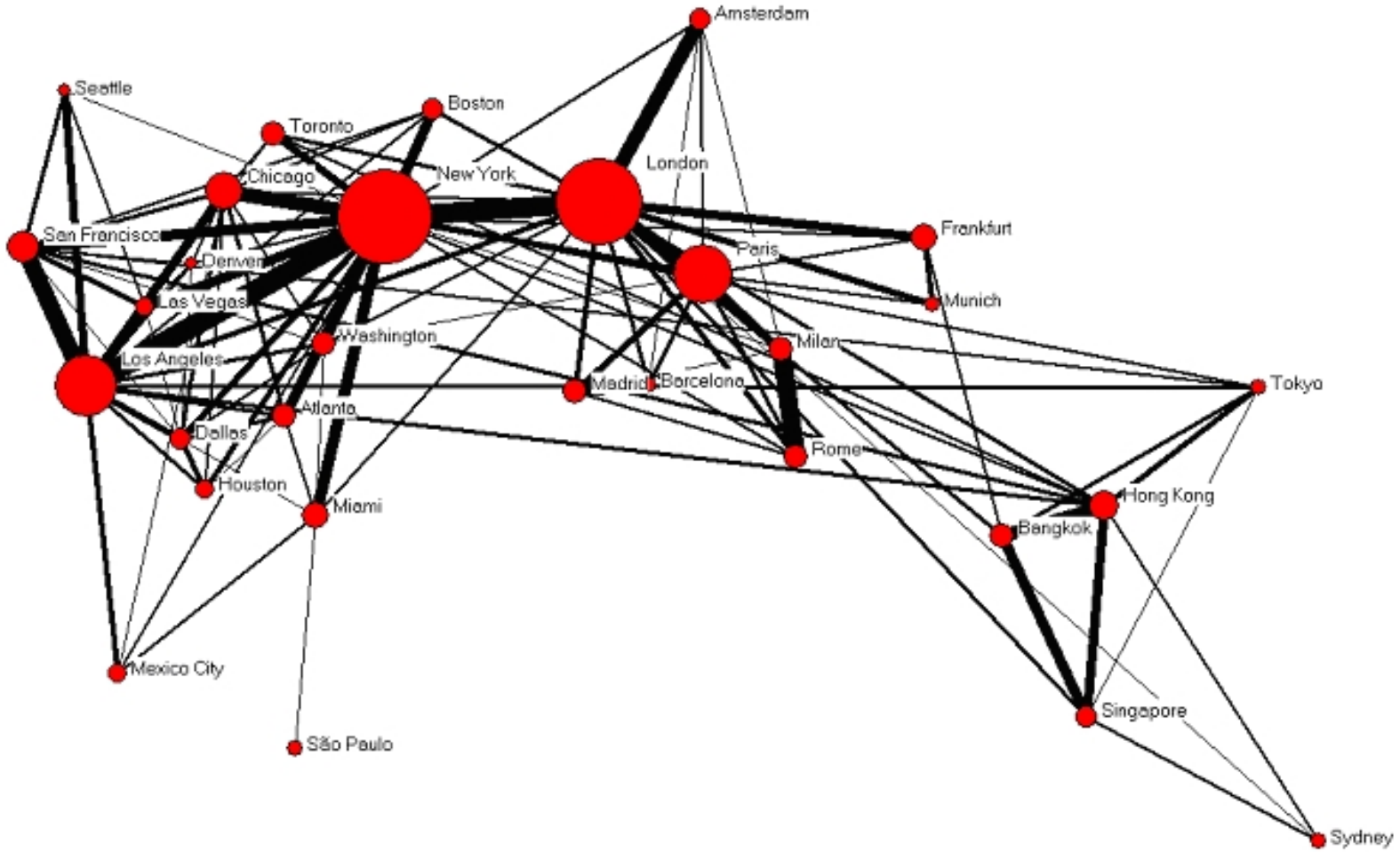
World City Research

- Local Structures in WCNs
  - Power and position of specific cities based on various city-level aggregated attributes
  - Three types of indicators



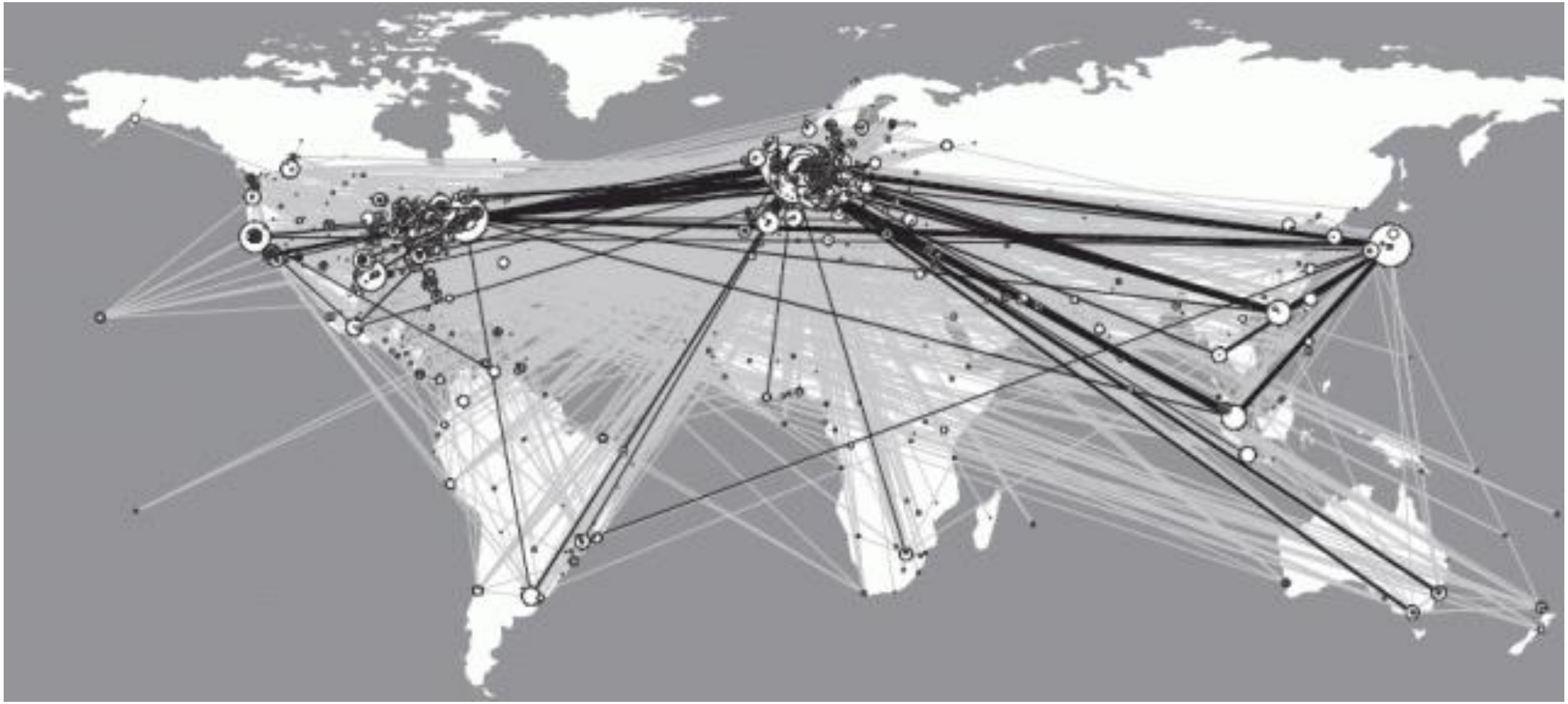
  - Measures of connectivity / centrality of a city node
  - Degree, interlocking network model
  - Closeness
  - Betweenness
  - Eigenvector centrality
  - Serves to sort and differentiate cities through **ranking**: Alpha cities, etc

World City Networks



(Derudder and Witlox, 2005)

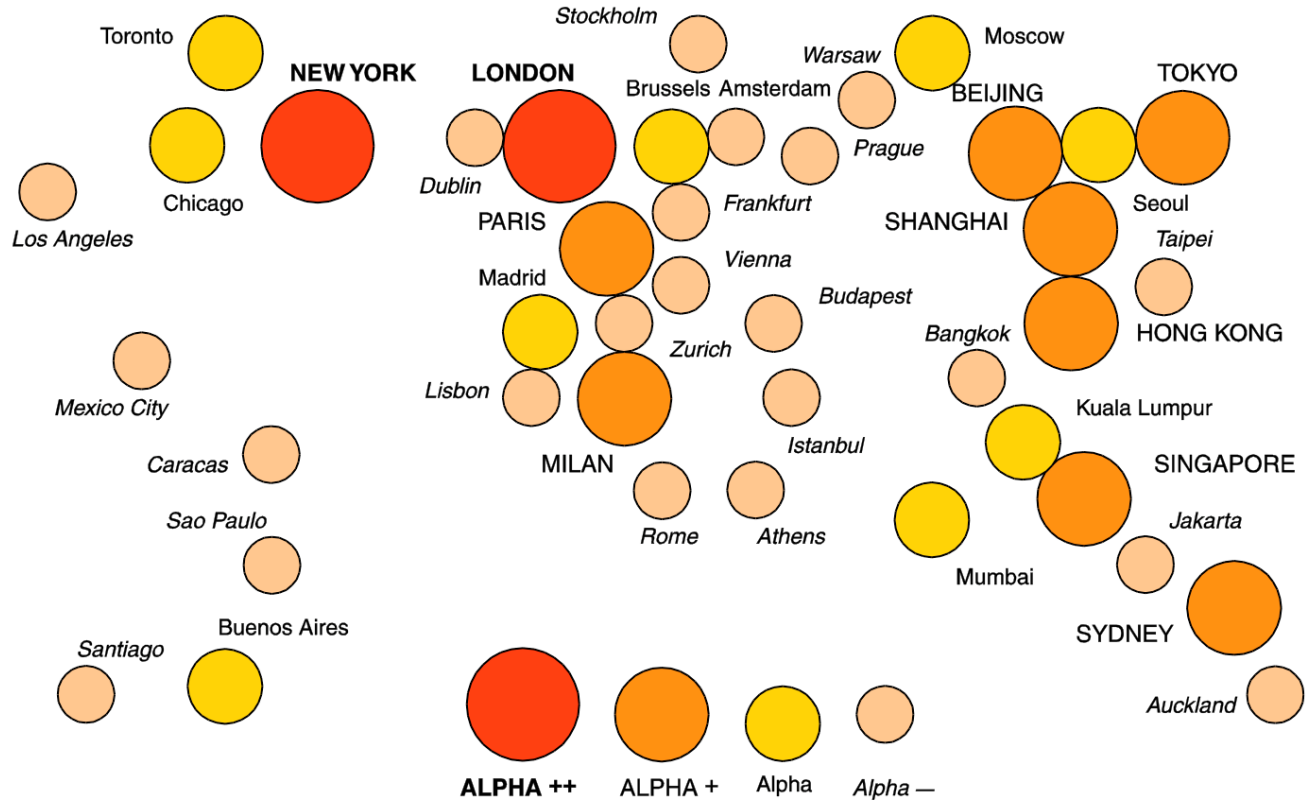
World City Networks



(R. Wall)

World City Research

- Globalization and World Cities (GaWC) Research Network collected data on 100 global advanced producer service firms (shared presence) and identified a global urban hierarchy



2004

The global urban network according to GaWC. www.lboro.ac.uk/gawc/.

World City Research

GaWC 2016 / Wikipedia

Alpha ++ cities are cities most integrated with the global economy:

- London
- New York City

Alpha + cities are highly integrated cities, filling advanced service needs:

- Singapore
- Hong Kong
- Paris
- Beijing
- Tokyo
- Dubai
- Shanghai

Alpha cities:

- Sydney
- Chicago
- Moscow
- Warsaw
- Seoul
- Jakarta
- Los Angeles
- São Paulo
- Mexico City
- Frankfurt
- Johannesburg
- Istanbul
- Amsterdam
- Milan
- Mumbai
- Madrid
- Toronto
- Kuala Lumpur
- Brussels

Alpha − cities:

- Dublin
- New Delhi
- Vienna
- Stockholm
- Manila
- Luxembourg
- Barcelona
- Melbourne
- Bangkok
- Taipei
- San Francisco
- Bogotá
- Riyadh
- Tel Aviv
- Washington, D.C.
- Zürich
- Buenos Aires
- Guangzhou
- Miami
- Santiago
- Lisbon

Beta level cities are cities that link moderate economic regions to the world economy and are classified in three sections, **Beta +**, **Beta**, and **Beta − cities**:

Beta + cities:

- Prague
- Copenhagen
- Atlanta
- Kiev
- Oslo
- Lima
- Cape Town
- Ho Chi Minh City
- Düsseldorf
- Bucharest
- Hamburg
- Dallas
- Lagos
- Athens
- Helsinki
- Bangalore
- Cairo
- Caracas
- Boston
- Munich
- Budapest
- Rome
- Houston
- Auckland

Beta cities:

- Doha
- Geneva
- Montreal
- Philadelphia
- Sofia
- Beirut
- Manama
- Karachi
- Montevideo
- Abu Dhabi
- Vancouver
- Perth
- Brisbane
- Nicosia
- Berlin
- Casablanca
- Shenzhen
- Hanoi
- Bratislava

Beta − cities:

- Port Louis
- Kuwait City
- Tunis
- Lyon
- San Salvador
- Monterrey
- Dhaka
- Minneapolis
- Chengdu
- Quito
- San José
- Antwerp
- Hyderabad
- Islamabad
- Chennai
- Panama City
- Belgrade
- Tianjin
- Zagreb
- Edinburgh

World City Research

Gamma level cities are cities that link smaller economic regions into the world economy, and are classified into three sections, **Gamma +**, **Gamma**, and **Gamma − cities**:

Gamma + cities:

- Guayaquil
- Cleveland
- Riga
- Baku
- Adelaide
- Vilnius
- Birmingham
- Glasgow
- Nanjing
- Hangzhou
- Colombo
- Porto
- Qingdao
- Valencia
- Detroit
- Muscat
- Osaka
- Ljubljana
- Kampala
- George Town
- Managua
- Durban
- San Jose
- Saint Petersburg

Gamma cities:

- Phoenix
- Tegucigalpa
- Austin
- Pune
- Guadalajara
- Dalian
- Tbilisi
- Dar es Salaam
- Chongqing
- Ankara
- Lusaka
- Ahmedabad
- Cincinnati
- Asunción
- Harare
- Gothenburg
- Xiamen
- Mosul
- Kansas City
- Accra
- Minsk
- Tampa
- Turin
- Luanda
- Abidjan
- Tirana
- Lausanne
- Leeds

Gamma − cities:

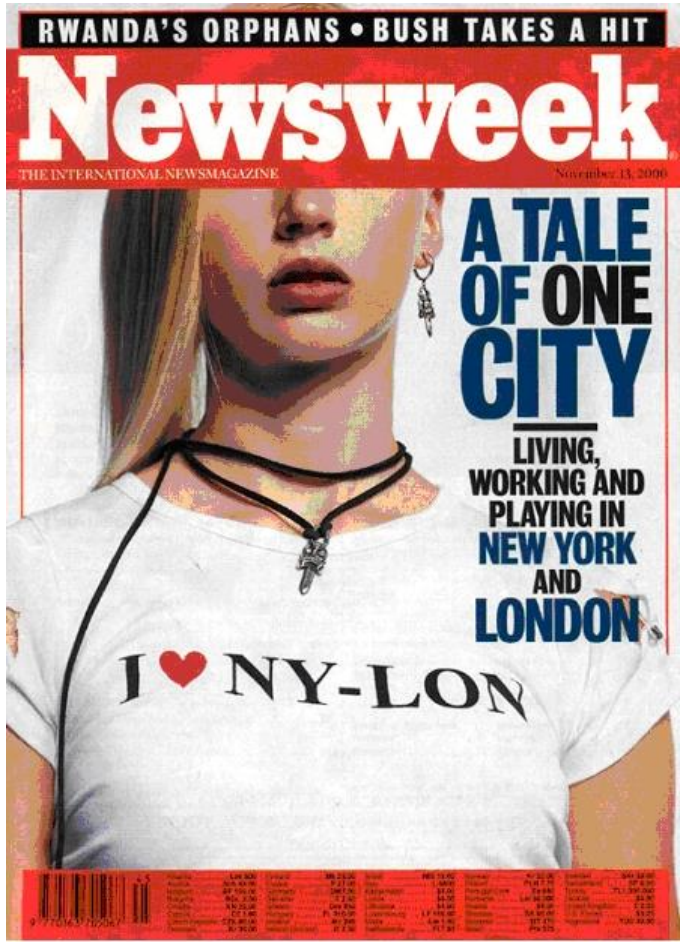
- Taichung
- Charlotte
- Baltimore
- Raleigh
- Belfast
- Leipzig
- Medellín
- Wuhan
- Douala
- Maputo
- Skopje
- Gaborone
- Bristol
- Orlando
- Dakar
- Suzhou
- Malmö
- Edmonton
- Changsha
- Strasbourg
- Bilbao
- Bologna
- Columbus
- Wellington
- Nuremberg
- Yangon
- Xi'an
- Wrocław
- Marseille
- Dresden
- Shenyang
- Pittsburgh

Sufficiency level cities are cities that have a sufficient degree of services so as not to be overtly dependent on world cities. This is sorted into **High sufficiency cities** and **Sufficiency cities**:

GaWC 2016 / Wikipedia

World City Research

- Globalization and World Cities (GaWC) Research Network collected data on 100 global advanced producer service firms and identified a global urban hierarchy



'NY-LON'

Newsweek
Nov. 13, 2000

World City Research

- Global Structures in WCNs
  - Classification or clustering: hierarchical levels
  - Conformity to 'laws'
  - Power law (complexity theory)

- Local and global approaches are quite data-driven and disconnected from socio-economic theories

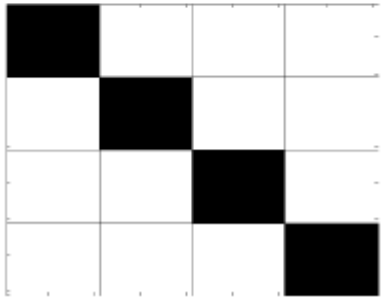
*"A hierarchy cannot be simply inferred from a ranking of cities; there have to be some form of **power relations** between the cities that sort them into a hierarchy. (Lukermann, 1966)*

Meso-scale Structures

- Meso-scale structures are less discussed in WCN literature
- Concept from network science
- Describes grouping properties that may not be apparent at either local or global scale
- In WCNs: partition of city nodes into groups based on their distinctive intercity interaction patterns (equivalent social positions)
- Presence of strong relational ties and similar positions compared to the rest of the world, instead of common individual features of city nodes (e.g., economic size) or the strength of their links (e.g., centrality)

Types of Mesoscale Structures

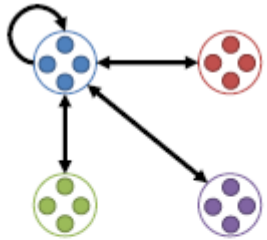
Associative Community

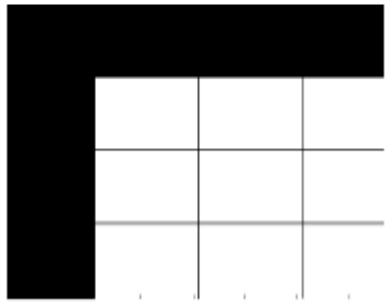


- Statistical clustering methods: PCA, fuzzy sets analysis
- Community detection algorithms: Louvain method, spin glass alg.

- Urban systems/city network within a region/country
- Territorialism (nationalization or regionalization)

Core-periphery Structure (Hierarchy)





- Alpha, beta, gamma cities
- World system theory
- Friedmann's (1986): world city hypothesis

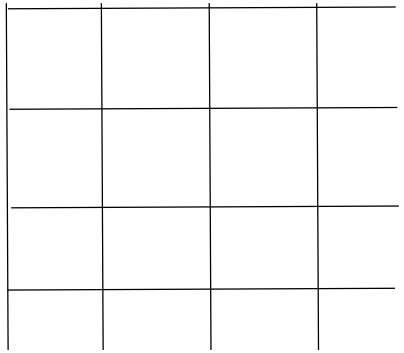
- K-cores, k-cliques, k-clan, k-club, p-plex, k-components

- Strong connections in core and with set of peripheral nodes that interact little among each other

(Rombach et al., 2013; Aicher et al., 2014)

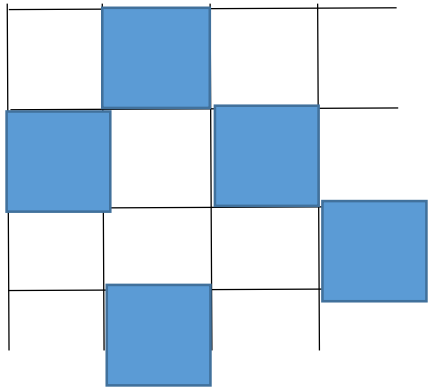
Types of Mesoscale Structures (II)

Flat world



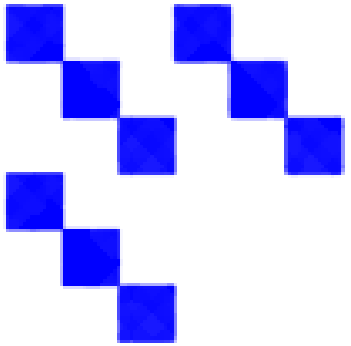
- No perceptible differences in connections by groups
- Lack of focal points
- Point-to-point
- Friedmann's *The World in Flat*

Bipartite structure

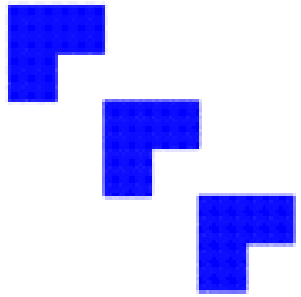


- Inverse of community structure
- Firm-by-city two-mode network

Hybrid structure (1): A global core-periphery structure with a regional community structure



Hybrid structure (2): A global community structure with a regional core-periphery structure



(Rombach et al., 2013; Aicher et al., 2014)

Mesoscale Structures

- Multiple types, each one rooted in its own imaginary of world organization
- Methodological determinism: methods are not neutral
- Hybrids are theoretically possible and empirically identified
- What analytical method to turn to?

Weighted Stochastic Block Model (WSBM)

- Based on blockmodeling, a method of positional and role analysis in SNA
- To identify prevailing mesoscale structures without assuming any specific structure a priori
- Classifies nodes into clusters and determines inter-cluster relational bundles such that nodes within the same cluster are deemed to have equivalent positions (i.e., equivalence)
- Like SBM (Holland et al., 1983), WSBM (Aicher et al., 2014) uses stochastic equivalence (as when 2 nodes have same probability to connect to nodes in other groups)
- Network is weighted
- Reverse inference process: given K latent groups and observed WCN, determine the latent grouping and stochastic block matrix
  - ML optimization

Which Intercity Relations?

- Well-documented intercity relations
  - Economic linkages (e.g., trade of commodities between cities, multinational corporations, financial flows)
  - Mobility linkages (e.g., intercity travel/freight flows by air or other modes)
  - Infrastructure linkages (e.g., transportation and telecommunication infrastructures)

- We use a document approach: the number of webpages at which two city names co-occur as the strength of relational ties (e.g., edges) between the two cities
  - Assumption 1: If two cities have more connections in cultural, economic and political domains, they can be more frequently referenced on webpages simultaneously
  - Assumption 2: The WCN structures may vary with languages (civilizations)

Analytical Process

1. Identifying the global cities based on existing literature
2. Selecting language(s)
3. Web crawling: using the Google advanced search engine to search for the co-word frequency of each pair of cities (names)
4. Applying the Weighted Stochastic Block Model (WSBM) to infer the mesoscale structure of the WCN

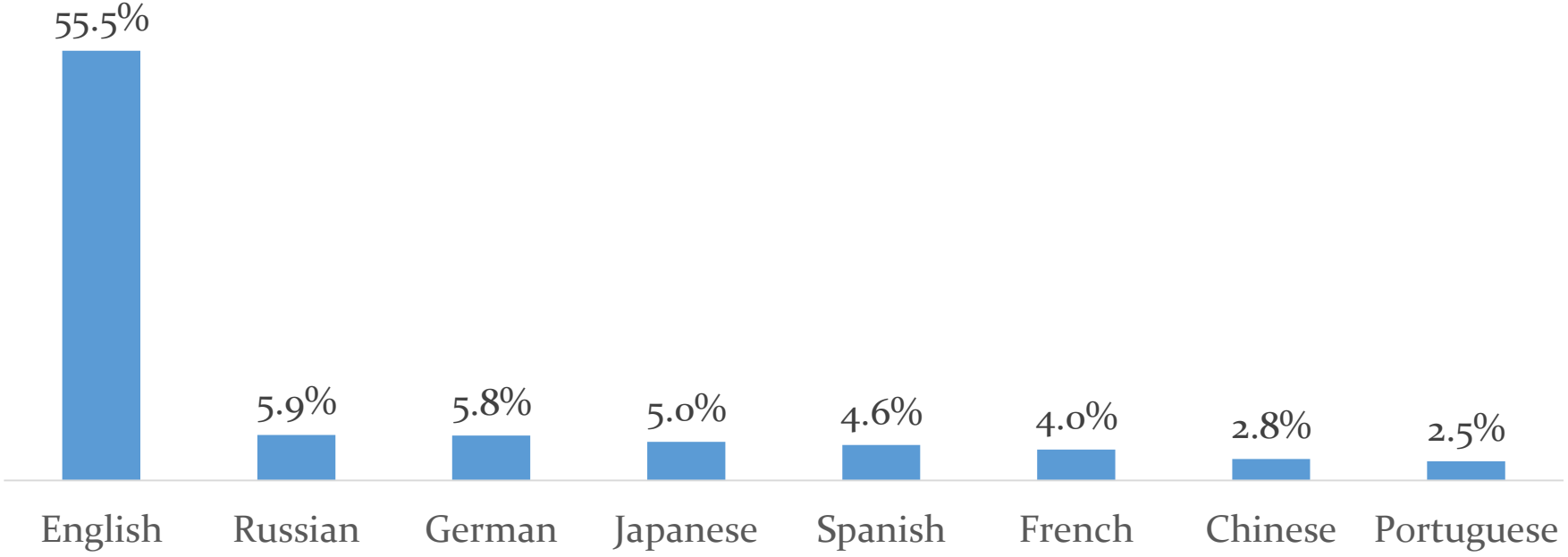
1. Selection of Cities

- The selection of cities may cause a major bias in the study of WCN (Robinson, 2002; 2005)
- We selected 126 cities that are identified by at least two among 22 literature references

Continents	No. of World Cities	% of Total
Africa	7	5.6%
Asia	42	33.3%
Europe	41	32.5%
North America	22	17.5%
Oceania	3	2.4%
South America	11	8.7%
Total	126	100.0%

2. Selection of Languages

- We chose the Top-Eight languages used in webpages based on data points in December 2015 from W3Techs.com, which monitors the top 10.1 million websites
- These languages cover 86% of the webpage languages used in the world while English is the dominant language for text communication on the Internet

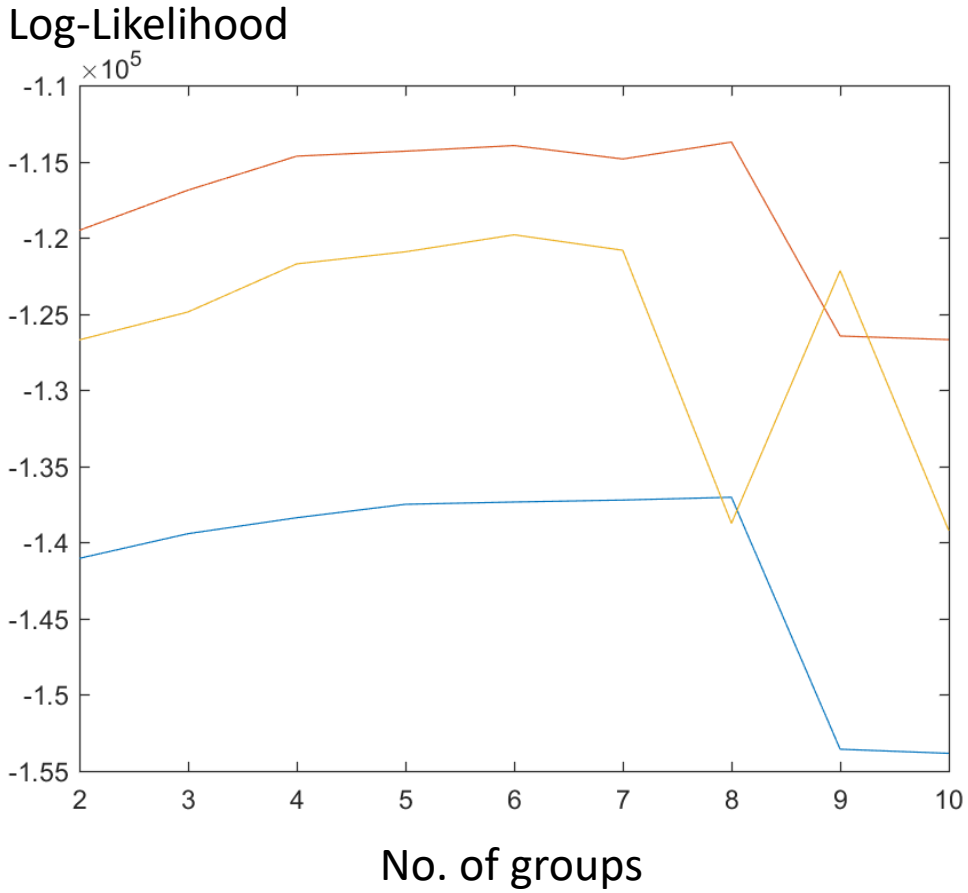


3. Web Crawling using Google's Advanced Search Engine

- Advanced Google Search can return hit counts (no. of webpages) by language
- For disambiguation, we used city + country name or state name as the search keywords, such as "Birmingham" and ("United Kingdom" OR "Britain" or "UK" OR "England"
- Google search may return fluctuating results; we searched 28 sets of data in one month (May 12-June 11) and selected the maximum numbers
  - Total number of searches was 441,000 (28*126*125)

4. Weighted Stochastic Block Modeling (WSBM)

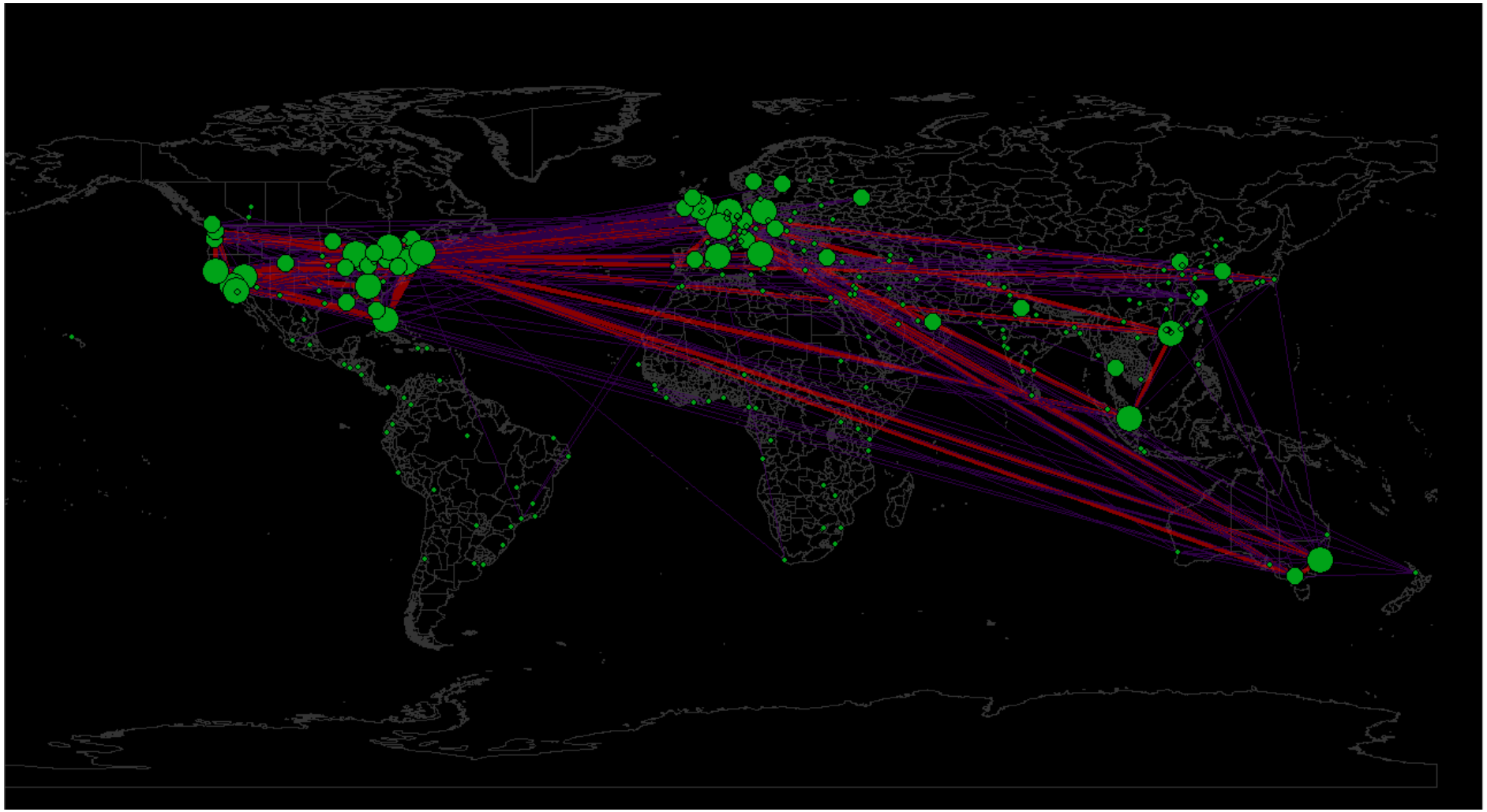
- The SBM is a popular generative model for learning community structure in social networks
- Variational Bayes algorithm (Aicher et al., 2015)



Findings

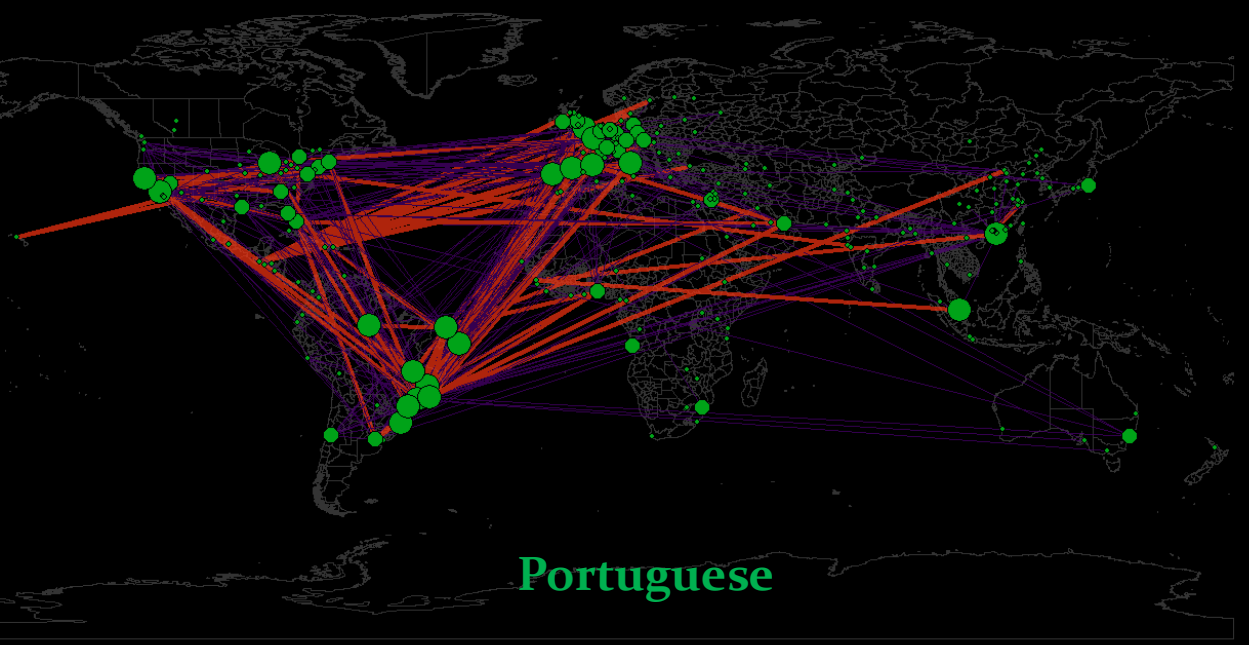
- Local and Global Structure (traditional approaches)
  - Ranking of city centralities
  - Ranking of city-dyads
- Mesoscale Structure (by language)

Geographic Distribution of City-Dyads (English)

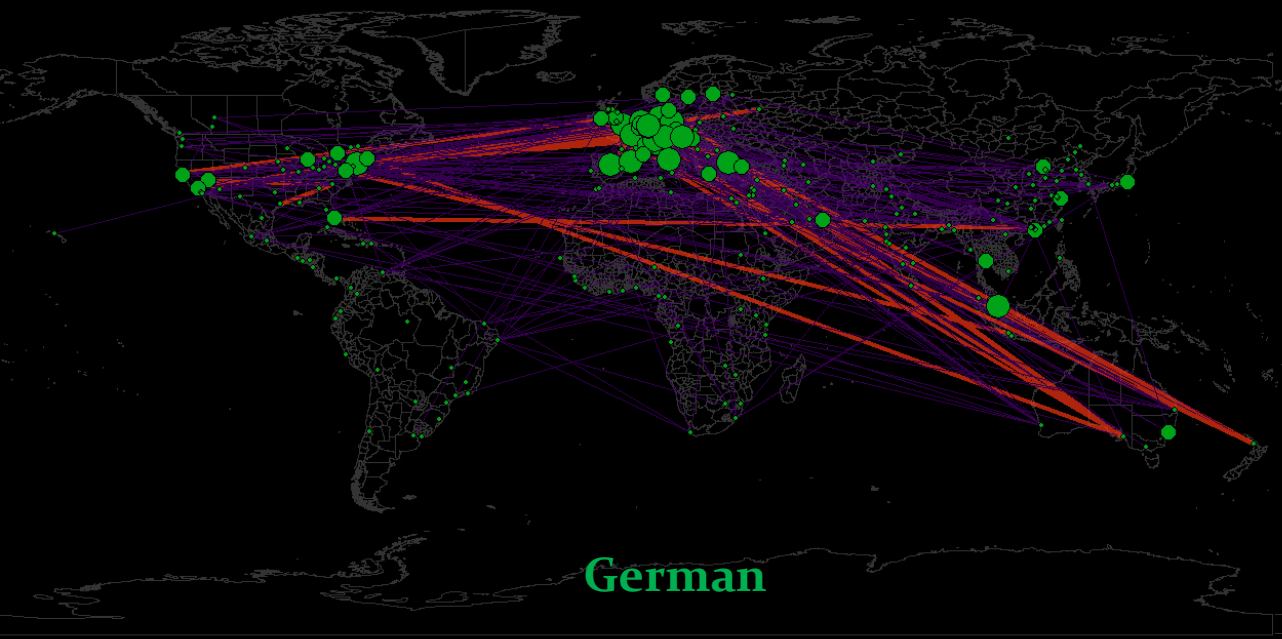


Lines with red colors: Top-100 city-dyad edges (ranked by the number of co-concurrence)
Lines with purple colors: City-dyads ranking from 101 to 500

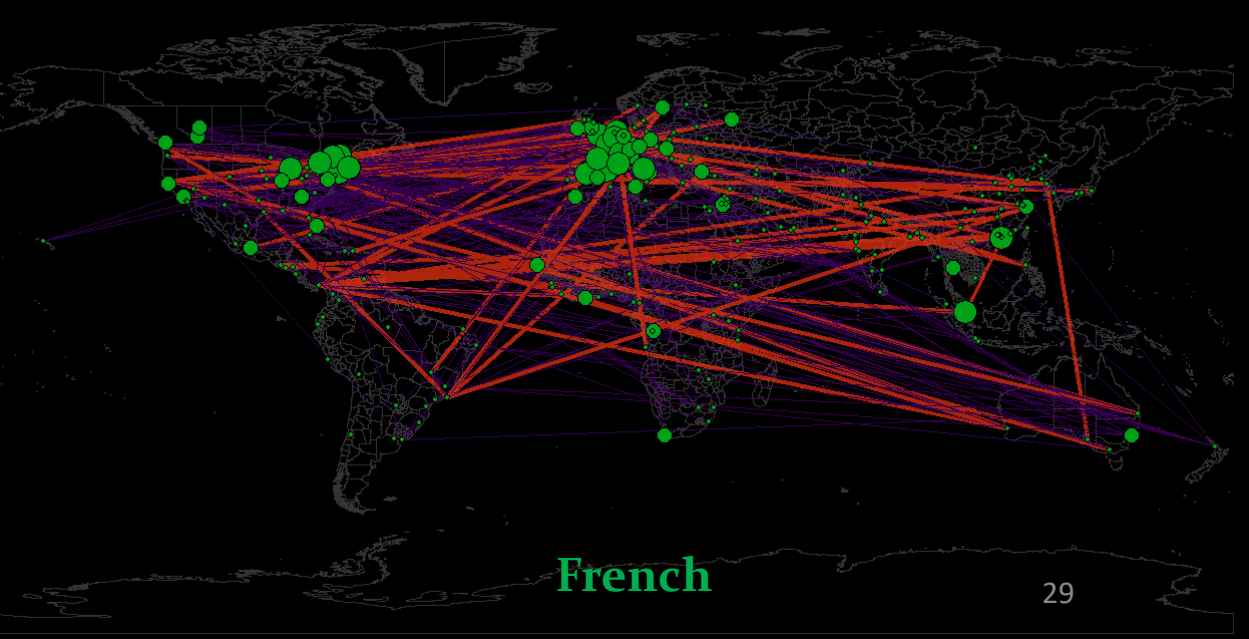
Spanish



Portuguese

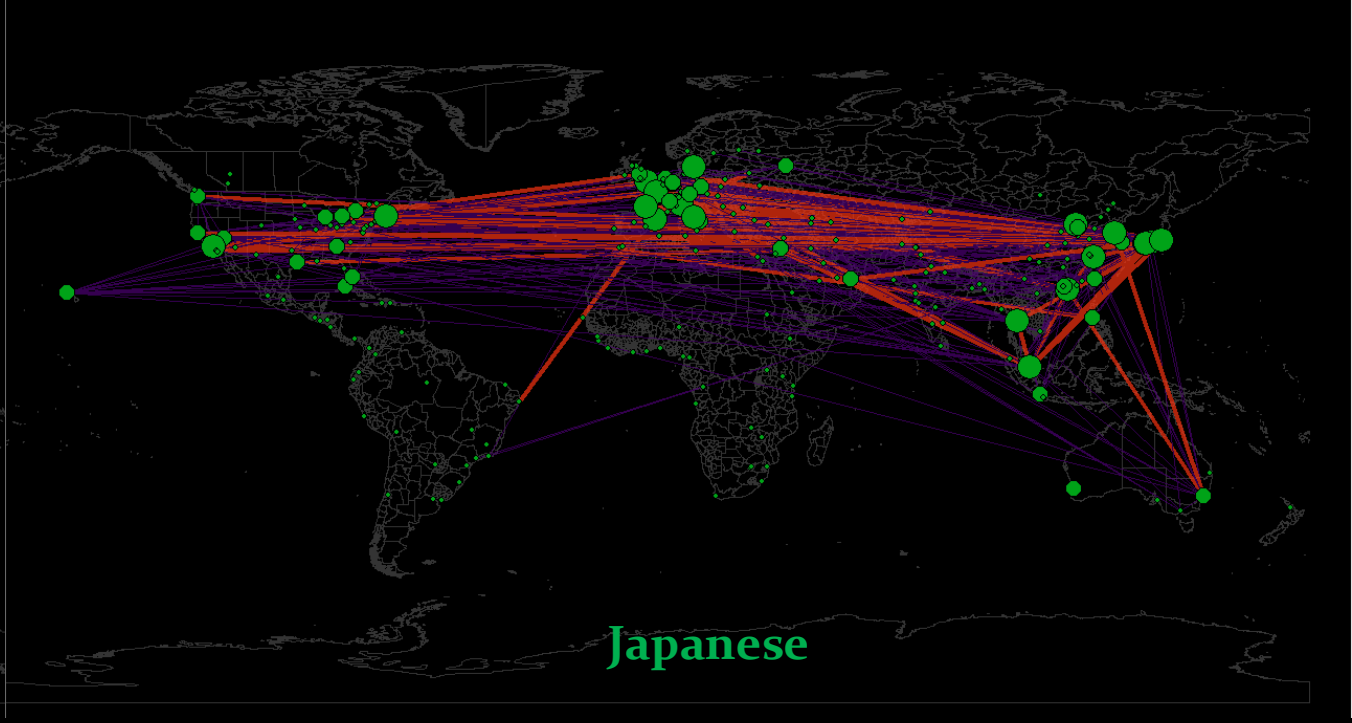


German



French

Russian



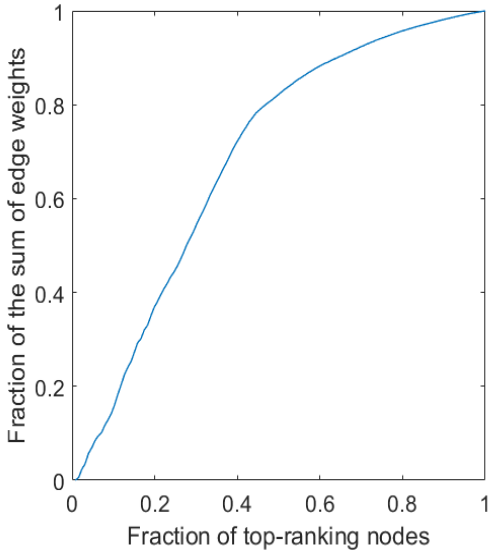
Japanese

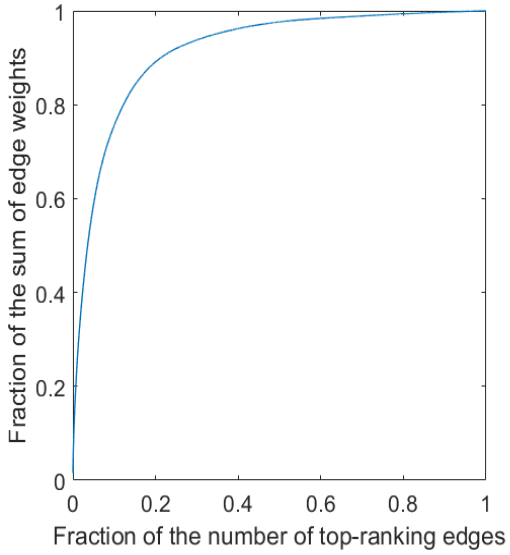
Simplified Chinese

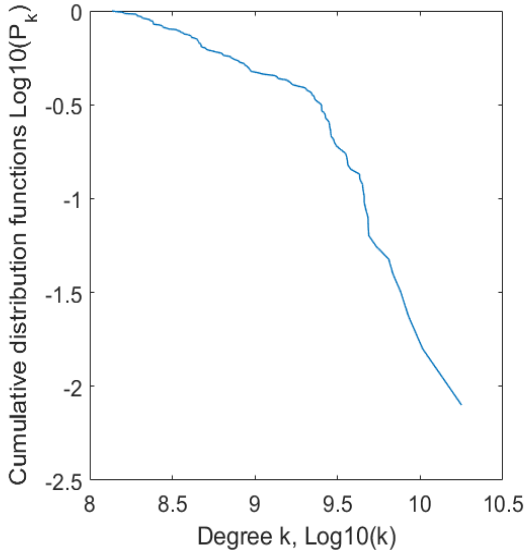
Traditional Chinese

Global/Local Structures

- Uneven geographic distribution of edge weights
- Uneven distribution of node centralities
- Uneven statistical distribution of edge weights
- Overall no power law, but piecewise we have a power law
  - Higher power for higher degrees (β = 2.9 vs 1.4)
  - Degrees are hierarchically distributed in top-40% cities



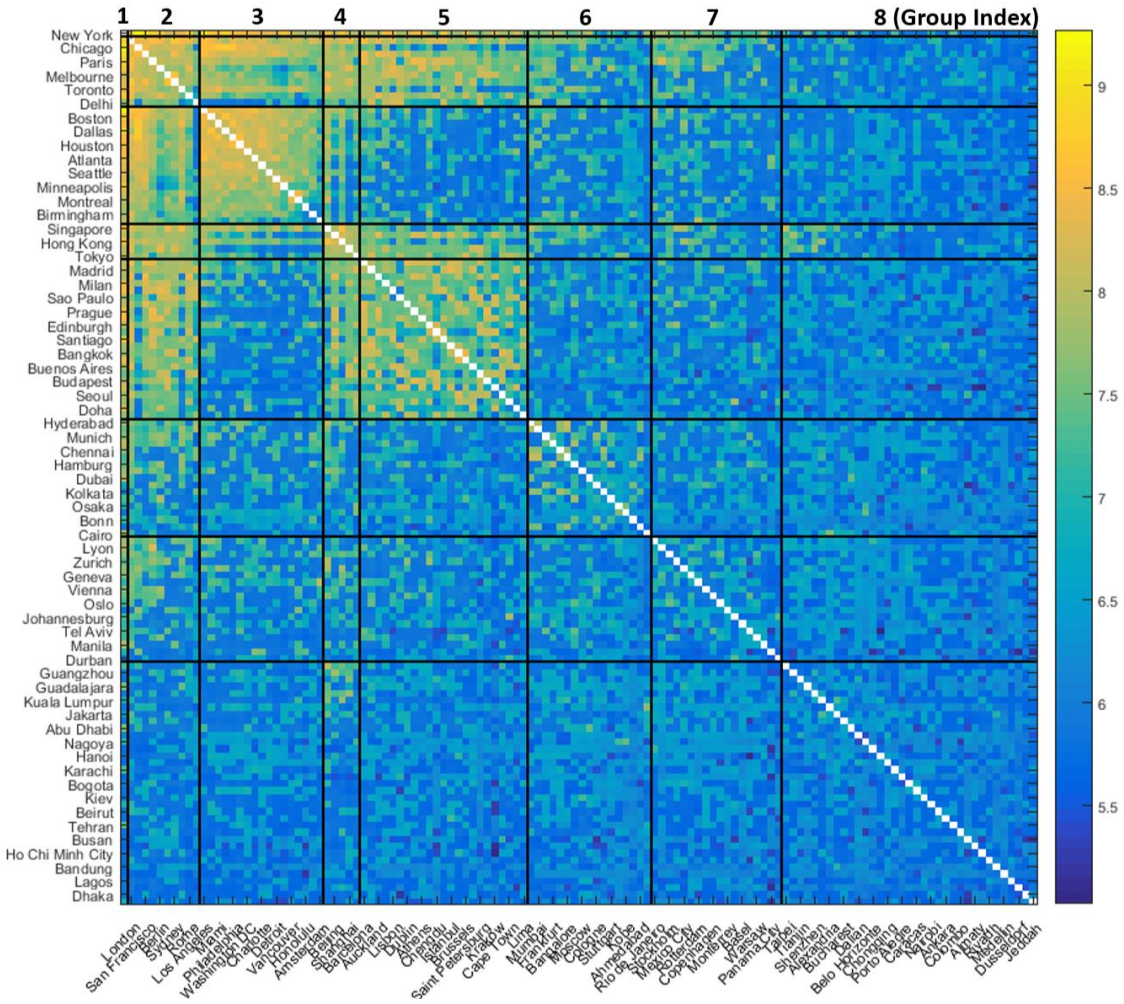




City ranking by degree centrality: Top-30 Cities (degree unit: billion webpages)

	City Names	Degree
1	New York	17.8
2	London	10.3
3	Chicago	8.5
4	San Francisco	7.6
5	Los Angeles	6.8
6	Paris	6.4
7	Boston	5.4
8	Berlin	4.9
9	Melbourne	4.8
10	Sydney	4.8
11	Toronto	4.7
12	Singapore	4.6
13	Miami	4.6
14	Dallas	4.5
15	Philadelphia	4.5
16	Houston	4.3
17	Rome	4.3
18	Barcelona	3.8
19	Washington DC	3.6
20	Atlanta	3.6
21	Beijing	3.6
22	Hong Kong	3.5
23	Madrid	3.3
24	Charlotte	3.1
25	Seattle	3.0
26	Auckland	3.0
27	Milan	2.9
28	Shanghai	2.9
29	Tokyo	2.9
30	Lisbon	2.8

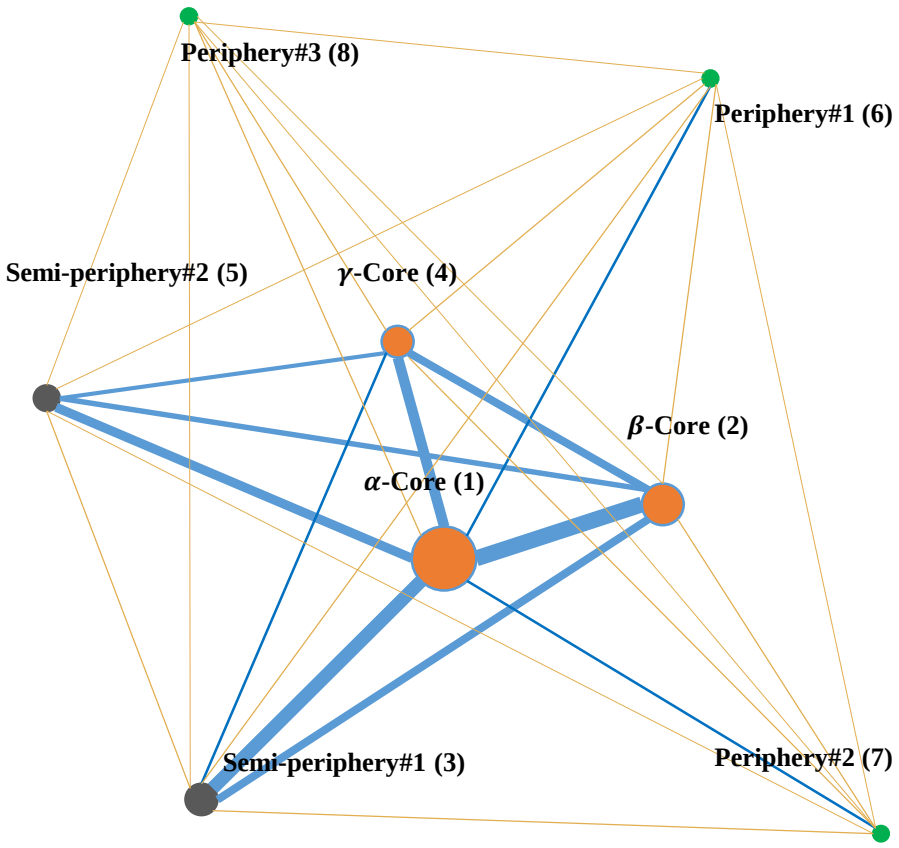
Detected Mesoscale Structure (based on English)



Pairwise city-based adjacency matrix (log10 of edge weights)

- Hybrid structure of multiple cores and peripheries instead of a single CP structure or community structure found in previous studies
- Mixed configuration of hierarchical and horizontal structures
- 8 groups

Detected Mesoscale Structure



Shrunk Network

Global Core

G1

New York

Macro-region Core

G2

London
Chicago
San Francisco
Paris
Berlin
Melbourne
Sydney
Toronto
Rome
Delhi

Semi-periphery

G3

Los Angeles
Boston
Miami
Dallas
Philadelphia
Houston
Washington DC
Atlanta
Charlotte
Seattle
Detroit
Minneapolis
Vancouver
Montreal
Honolulu
Birmingham
Amsterdam

Macro-region Core

G4

Singapore
Beijing
Hong Kong
Shanghai
Tokyo

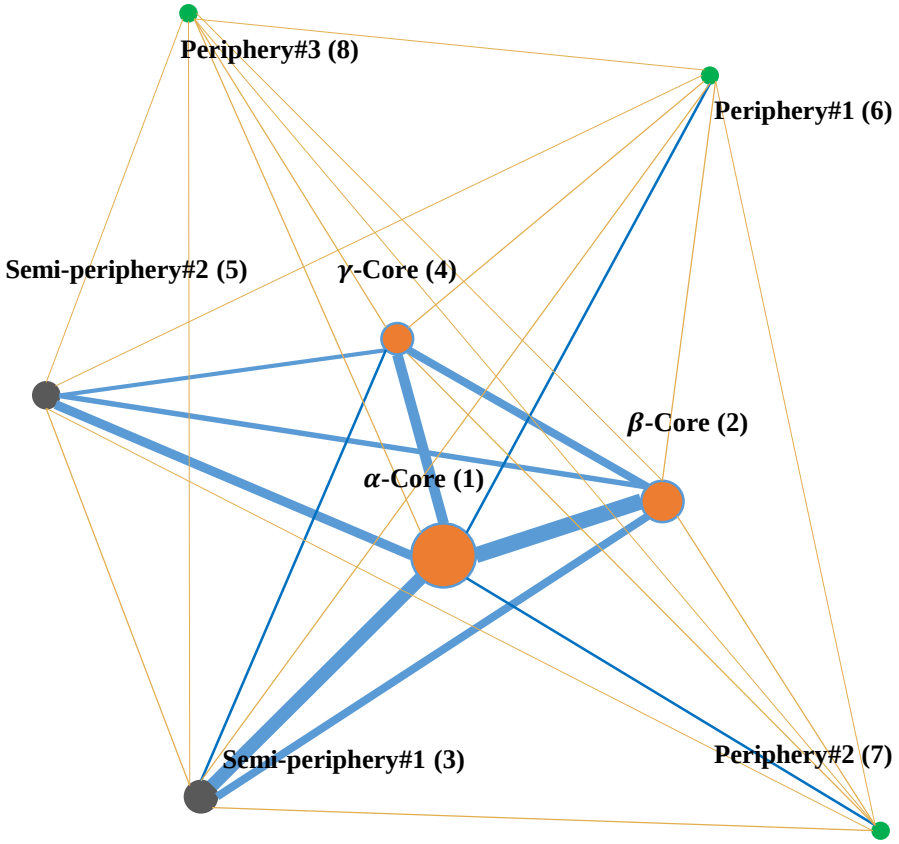
Semi-periphery

G5

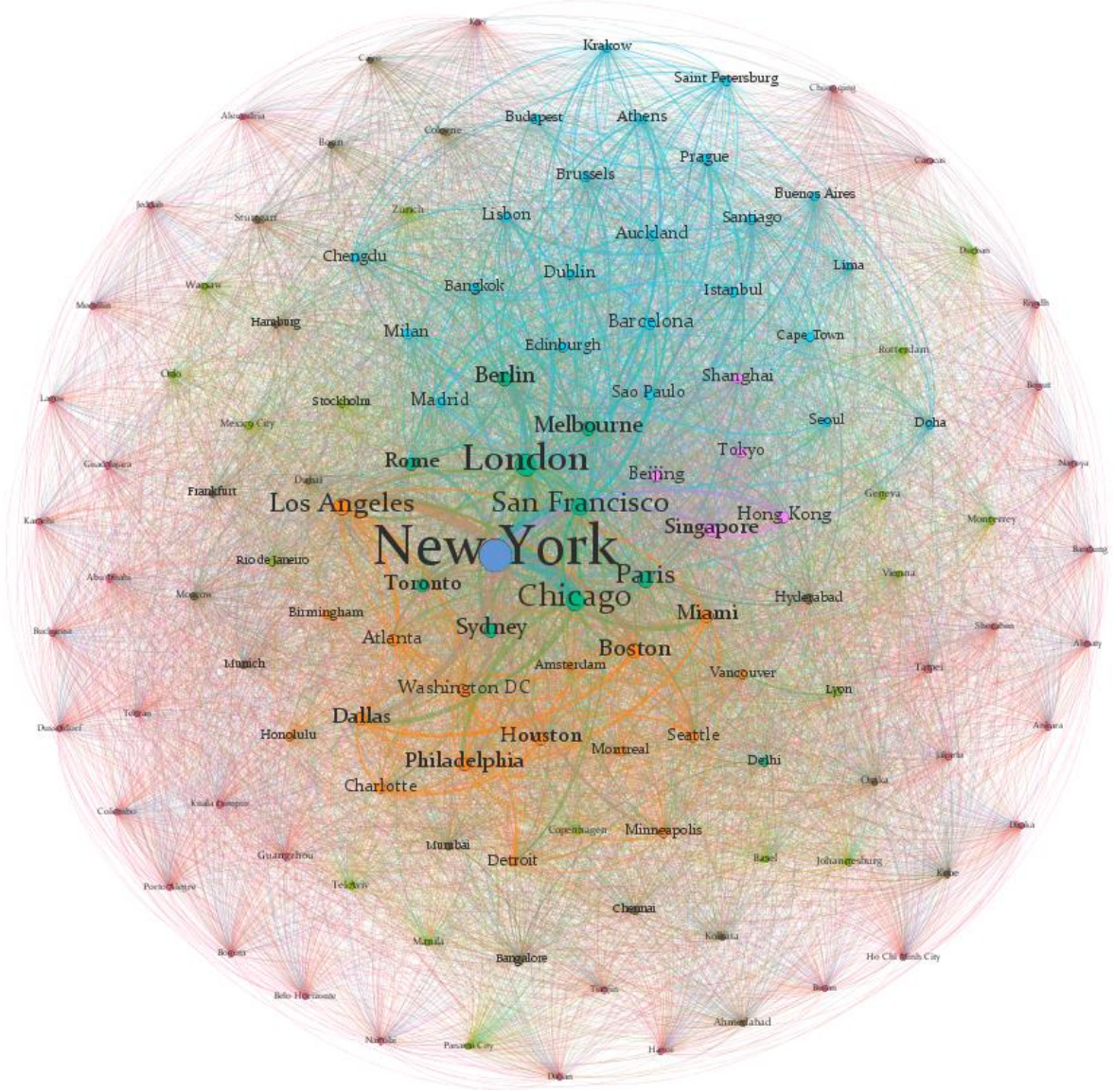
Barcelona
Madrid
Auckland
Milan
Lisbon
Sao Paulo
Dublin
Prague
Athens
Edinburgh
Chengdu
Santiago
Istanbul
Bangkok
Brussels
Buenos Aires
Moscow
Budapest
Krakow
Seoul
Cape Town
Doha
Lima

Detected Mesoscale Structure

- G3 and G5: semi-peripheral
  - G3 is mainly American
  - G5 is the rest of the world
  - G3 and G5 are well connected to cores
  - G3 and G5 are weakly connected to each other



The WCN



Group (City No.)	Cities	Roles
1 (1)	New York	α-Core
2 (10)	London, Paris, Berlin, Rome, Chicago, San Francisco, Toronto, Melbourne, Sydney, New Delhi	β-Core
3 (17)	Los Angeles, Boston, Miami, Dallas, Philadelphia, Houston, Washington DC, Atlanta, Charlotte, Seattle, Detroit, Minneapolis, Honolulu, Vancouver, Montreal, Birmingham, Amsterdam	Semi-periphery #1
4 (5)	Singapore, Beijing, Hong Kong, Shanghai, Tokyo	γ-Core
5 (23)	Barcelona, Madrid, Milan, Lisbon, Dublin, Prague, Athens, Brussels, Edinburgh, Istanbul, Saint Petersburg, Budapest, Krakow; Sao Paulo, Buenos Aires, Santiago, Lima; Seoul, Bangkok, Chengdu, Doha; Auckland; Cape Town	Semi-periphery #2
6 (17)	Munich, Frankfurt, Hamburg, Stuttgart, Cologne, Bonn, Moscow; Mumbai, Chennai, Bangalore, Dubai, Kolkata, Hyderabad, Ahmedabad, Osaka, Kobe; Cairo	Periphery#1
7 (18)	Lyon, Stockholm, Zurich, Geneva, Rotterdam, Vienna, Copenhagen, Oslo, Basel, Tel Aviv, Warsaw; Rio de Janeiro, Mexico City, Monterrey, Panama City; Johannesburg, Durban; Manila	Periphery#2
8 (35)	Taipei, Guangzhou, Tianjin, Shenzhen, Chongqing, Dalian, Kuala Lumpur, Jakarta, Abu Dhabi, Nagoya, Hanoi, Karachi, Beirut, Tehran, Colombo, Busan, Almaty, Ho Chi Minh City, Riyadh, Bandung, Dhaka, Jeddah; Guadalajara, Belo Horizonte, Porto Alegre, Bogota, Caracas, Medellin; Bucharest, Kiev, Dusseldorf, Ankara; Alexandria, Nairobi, Lagos	Periphery#3

Take Aways / Conclusions

- Alternative mesoscale structures can be uncovered without methodological determinism
- Mesoscale structure hidden in a world city network is more interesting than those local measures/rankings (e.g., city centrality & dyads), since it directly shows the structure of network (rather than the structure of city nodes/links).
- The world city network ➔ The world city *networks*
  - *The world city networks found in English webpages appear to be hierarchical and with multiple cores attached by different peripheries.*
- Structure in WCN does not equate to hierarchy
- Uncovered mesoscale structures have some geographic expression, yet the mesoscale structures transcend the territorialist view. Functional relations trump geography.
- Scale in World City Networks matters!

Thank You for Your Attention!

Questions? Comments?

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