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Maritime shifts in the contemporary world economy: evidence from the Lloyd's List corpus, 18th-21st centuries

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The *Lloyd's List* records on vessel movements are certainly the only possible source for mapping and analysing the global evolution of ports and maritime networks over the last 120 years. However, very rare reference to *Lloyd's List* is made in the literature. The first ever analysis we found dates back to the mid-1950s. Motivated by the pedagogical potential of the source for port study in schools, the geographer Henry Rees (1955) proposed a few maps of vessel movements that took place between the terminals of selected British ports. Much later, another geographer having worked 15 years in the shipping industry underlined in a footnote that “a very useful source (...) might be *Lloyd's Shipping Index*” (Fleming, 1968, p. 35) but without using it. In the second half of the 1970s, two reports proposed to map ship traffic densities at world scale using the latter source, based on a square grid and the extraction and computation of vessel movements from the *Lloyd's Shipping Index* (McKenzie, 1975; Solomon et al., 1978). A few years later, the Australian Bureau of Transportation Economics published a report using vessel movement data from *Lloyd's Voyage Record* to measure the impact of introducing fully cellular containerships on Australian ports (BTE, 1982), but it is only 20 years later that this source was used to analyse the distribution of ship calls in the Baltic region (Swedish Maritime Administration, 2000).

Most of the time, *Lloyd's List* is used for genealogic investigations, for instance to retrieve a given ship or voyage based on someone's memoirs, for underwater archaeology, such as to inventory the exact location of sunk ships in Irish waters over the period 1741-1945 (Brady, 2008), or to analyse the activity of one given port on the basis of vessel calls, such as Whitby over the period 1700-1914 (Jones, 1982). Several other usages could have been reported, but they differ drastically in their objective and scope: the calculation of time difference evolution between sailing date and publication date to study the changing speed of information transmission in modern times (Kaukiainen, 2001); or the spread of Spanish flu through shipping in

1918 in the island of Newfoundland (Palmer et al., 2007). As mentioned in the introductory chapter, it is only in the very late 1990s that a systematic analysis of containership movements listed in *Lloyd's Voyage Record* was proposed at the global scale to reveal the macro-structure of the maritime network based on graph theory (Joly, 1999). Later on, more regional analyses were proposed using digital records provided by *Lloyd's Marine Intelligence Unit* to analyse the Caribbean basin (Veenstra et al., 2005) and inter-Korean maritime flows (Ducruet et al., 2008); it later was expanded to analyse the long-term evolution of port hierarchies and network topologies on a larger scale (Ducruet, 2013).

Several fundamental questions remain unanswered, such as why has *Lloyd's List* data been mentioned or analysed so late, given its long-term existence and its uniqueness in terms of publication frequency (daily vessel movements) and geographic coverage? *Lloyd's* has long been the largest classification society, with a market share of around 42 percent of the world fleet throughout the period 1910-1922 (Richardson and Hurd, 1923), and about 9.7 percent nowadays. One reason given by historians is the traditionally qualitative character of maritime history and hence, its reluctance to compile large datasets. This cannot suffice to explain why other researchers underused this source over the last century, given the early quantitative analyses of maritime flows by geographers based on other sources (see a review in Chapter 1 by Ducruet). The limited diffusion of technical reports on ship densities, data cost restricted access - *Lloyd's* publications were primarily targeting the shipping industry – are also not obvious factors since British libraries have been holding such documents for decades: any scholar could have extracted the data manually to undertake the analysis of even a small region.

After reviewing the contents of this corpus since its first publication in 1696, we introduce the methodology used to extract shipping information from printed documents. The core of the analysis focuses on regional shifts in the geographic distribution of maritime routes and port hierarchies over the period 1890-2008. This chapter particularly discusses the uneven diffusion and impact of technological innovation (e.g. sail, steam, combustion, mega-carriers), the long-term evolution mechanisms of ports, port systems and maritime networks, the disaggregated distribution of global trade in relation with wider economic and (geo)political changes, refining previous attempts on the matter (Ducruet and Marnot, 2015; Ducruet, 2015).

The *Lloyd's List* corpus on global vessel movements

The "List": a short historical survey

'He's lost, gentlemen,' [...], 'he's lost a hundred times over! As you know, the *China* arrived yesterday - the only steamship from New York that he could have caught to

Liverpool. Now here is a list of passengers published by the *Shipping Gazette*, and Phileas Fogg's name is not on it.¹

These words had been pronounced by *Andrew Stuart*, a member of the *Reform Club* and a character of the famous adventure novel by the French writer *Jules Verne*, published in 1873, *Around the World in Eighty Days*. Stuart came to this conclusion thanks to information from a newspaper which really did exist and entitled the *Shipping Gazette*. The *Shipping and Mercantile Gazette* was a competitor since 1836 of the famous *Lloyd's List* in the field of shipping and maritime intelligence.

Lloyd's List belongs from the beginning to Marine lists, a publication reporting overseas trade and shipping. Even if the first issue of *Lloyd's List* had been printed in 1735, historical research show that its origins date back to the late seventeenth century², with the creation by *Edward Lloyd* (circa 1648-1713), founding proprietor of the famous eponymous coffee house, of a newspaper entitled *SHIPS Arrived at, and Departed from several Ports of England, as I have Account of them in London [...]* *An account of what English Shipping and Foreign Ships for England, I hear of in Foreign ports*. (McCusker and Gravesteijn, 1991; McCusker, 1991, 1997, 2005).

The later history of *Lloyd's List*, which is descended from *Edward Lloyd's* newspaper, is better known. The original newspaper died out circa 1772 with the founding in 1769 of a *New Lloyd's Coffee House* by a dissident group of marine insurers and the publication of *New Lloyd's List*, shortened *Lloyd's List* in 1789. Publication under this title continued to 1871, when the newspaper was renamed *Lloyd's List and Commercial Daily Chronicle*. From June 1884 to July 1914, *Lloyd's List* is amalgamated with the *Shipping and Mercantile Gazette* and published as *Shipping and Mercantile Gazette & Lloyd's List* (Fayle and Wright, 1928; Barriskill, 1994; Hailley and Landon, 2009). Printed under its original title after 1914, the newspaper was renamed between 1922 and 1969 and issued as *Lloyd's list and shipping gazette*.

¹ Extract from Verne J. (1995), *The Extraordinary Journeys, Around the World in Eighty Days*, Oxford and New York: Oxford University Press. This edition had been translated with an introduction and notes by William Butcher. According to him, the *Shipping Gazette* is the *Shipping Gazette & Lloyd's List Weekly Summary*, published in London between 1856 and 1909. In fact, the *Shipping and Mercantile Gazette* had been combined with *Lloyd's List* between 1884 and 1914 under the title *Shipping and Mercantile Gazette & Lloyd's List* (Barriskill, 1994).

² Thomas Jemson (Master of Lloyd's Coffee House from 1728 to 1734) is regarded by most historians as the planner of the paper, and Richard Baker (Master of Lloyd's Coffee House from 1738 to 1748), as *Lloyd's List* first editor and publisher (Fayle and Wright, 1928; Hailley and Landon, 2009; Lloyd's Register Foundation, Infosheet No. 16, 2014), while Edward Lloyd is considered as founder of the one and only *Lloyd's News*, a general political newspaper, with shipping intelligence from the ports but no regular lists. Recent evidence produced by John McCusker shows that Edward Lloyd founded a second newspaper which will become *Lloyd's List* in 1735.

Renamed again *Lloyd's List*, one of the oldest newspaper in England is published till December 20, 2013 and then replaced by digital format³.

The strength of *Lloyd's List* lies, since its origins, in that it provides a constantly updated shipping and maritime intelligence. As early as *Edward Lloyd's* time, collection of shipping information was made possible thanks to a network of correspondents, organised latter in agencies and sub-agencies, with appointed staff since 1811 (Fayle and Wright, 1928). *Henry Fry* (1826-1896), President of the *Dominion Board of Trade of Canada* in 1873, wrote that Lloyd's agents, whose principal task was to supply regular shipping intelligence, “[...] are found at nearly every seaport in the world, and exercise a sort of control over the wreck of every British ship, whilst more marine insurance is effected at the head office than in any similar institution known”⁴. Fry was himself appointed Lloyd's agent at Quebec in 1856. Between 1820's and 1920's, the number of Lloyd's agencies and sub-agencies increased five times and a half⁵.

Transmission of collected shipping and maritime information to London was improved since Lloyd's early existence thanks to particular arrangements and regular innovations. The early one was a special agreement with the Post Office - probably since Edward Lloyd's time – which gave a preferential priority treatment to dispatch letters from Lloyd's correspondents to London (McCusker, 1991). In the second half of the 19th century, on Lloyd's own initiative, a network of signal stations was deployed⁶, thereby increasing accuracy of shipping movement information. Lloyd's introduction of technical progress, like wireless telegraphy or use of night signal flashing lamp aboard, contributed to set up a 'world wide net' (Fayle and Wright, 1928), but also increased amount and quality of collected shipping and maritime data. Even if other factors had to be taken into consideration, and particularly a global

³ The evolution of Lloyd's periodical publications is reported by several info sheets and guides (see references), online libraries catalogues – i.e. British Library and Copac (<http://copac.ac.uk/>) – and original issues from *World Seastems Project* collections. It seems that no exhaustive historical study had been made about the whole Lloyd's publication corpus.

⁴ Extract from Fry H. (1895) *Lloyd's, its Origin, History and Methods*. Québec: Dawson & Co. This booklet is available online (https://archive.org/details/cihm_91606). For more biographical information, see: Marcil E. (2003) Fry, Henry. In *Dictionary of Canadian Biography*, vol. 12, University of Toronto/Université Laval, 2003, also available online (http://www.biographi.ca/en/bio/fry_henry_12E.html).

⁵ In 1820, the total number of Lloyd's agencies and sub-agencies was 274. In 1928, it was 1,500 (Fayle and Wright, 1928).

⁶ The first Lloyd's signal station was established in 1869. In 1884, 17 signal stations in U.K. and 6 abroad were at Lloyd's disposal. In 1891, the number of Lloyd's signal stations was 40 in U.K. and 118 overseas. In 1928, it was 28 in U.K. and 134 abroad (Fayle and Wright, 1928).

improvement in the speed of information transmission, Lloyd's Corporation adapted its practice, taking part in second half of 19th century world shrinking⁷.

The first Lloyd's Act passed in Parliament in 1871, besides the fact that it laid the legal foundations of Lloyd's Corporation, specified the collection, publication and diffusion of intelligence and information as one of the objects of the Society. It was confirmed by the Lloyd's Act of 1911⁸. It is not a coincidence if at that time Lloyd's Corporation began to increase the number of reference books and periodical publications in the field of shipping and maritime intelligence.

Lloyd's periodicals, a Sargasso Sea for researchers

Despite the publishing of several research guides – and particularly the various editions of Barriskill's dedicated to Lloyd's marine collection held by Guildhall Library – it is not an easy thing to navigate through Lloyd's publications.

First, each type of publication was distilled from specific data among shipping and maritime information collected by Lloyd's agents and correspondents. An advertising insert published in 1923 edition of *Brassey's Naval and Shipping Annual* put forward no less than seven publications: *Lloyd's List and Shipping Gazette*, described as the 'Leading Daily Shipping Newspaper', providing readers with complete shipping intelligence; *Lloyd's Daily Index*, the 'only complete publication of its kind', dealing with vessel movements engaged on oversea trade; *Lloyd's Loading List*, 'a complete list of Vessels loading for Coastwise and Foreign Ports'; *Lloyd's Weekly Casualty Reports*, providing 'a complete list of Marine Casualties, Missing and Overdue Vessels'; *Lloyd's List Weekly Summary*, giving a résumé of shipping news with an 'exclusive list of Vessels Outward and Homeward bound'; *Lloyd's List Law Reports*, treating of maritime and commercial law cases reported in *Lloyd's List*, with verbatim reports of judgments; and *Lloyd's Calendar*, an annual seamen's almanac with 'information of value to all connected with Shipping'⁹.

Additional confusion stemmed from title variability for periodicals, periodicity fluctuation, multiple editions, and changes in issue numbering. The aforementioned *Lloyd's List* is not the only case. For example, *Lloyd's Loading List* is a weekly periodical published by Lloyd, with its first issue in 1920 under this title. However, *Lloyd's Loading List* absorbed an older periodical, *The general weekly shipping list*

⁷ About information revolution in 19th century, see: Kaukiainen Y. (2001). Author based his research about improvements in information transmission based on material extracted from *Lloyd's List*.

⁸ Lloyd's Act of 1871 and 1911 are available online (<http://www.lloyds.com>).

⁹ Richardson M.P., Hurd A. (eds) (1923) *Brassey's Naval and Shipping annual*, London: William Clowes and sons, available online (<https://archive.org/details/brasseysnavala1923brasuoft>). The aforementioned advertising insert is entitled 'Lloyd's shipping publications' and is placed page XVII. The list drawn up is not complete: this advertising insert does not mention other Lloyd's publications, like the famous Lloyd's Register of Shipping, an annual list of vessels published since the mid-18th century.

and postal and mercantile directory, published in London since 1853. Using the *Lloyd's Loading List* corpus is complicated due to numerous editions: original U.K. and, since 1978, a 'Continental edition', renamed 'European edition' in 1980. Another issue is editing discontinuation, such as for *Lloyd's List Weekly Shipping Summary*, which last issue is dated August 1934. Finally, among Lloyd's publications, we can notice a kind of "ghost" periodical, the *Voyage Tables of Steamers*, a half-yearly table published since the end of 1883, providing the number of voyages made by any steamer during the previous twelve months. This periodical, mentioned in 1885 edition of *Hints to Captains of the Mercantile Marine*, is nowhere to be found¹⁰.

For researchers, a final difficulty concerns the sensitive nature of shipping and maritime information – especially data about shipping movements – provided in Lloyd's publication. It is no accident that it was decided to extract shipping movements and casualties from *Lloyd's List* between January 1917 and November 1918, information separately printed as a restricted publication (Barriskill, 1994). In the same period, publication of *Lloyd's Weekly Index* was suspended¹¹. This was due to Germany's resumption of unrestricted U-boat warfare in 1917, because of the risk to provide to Imperial German Navy strategic information about shipping movements¹². Since 'loose lips might sink ships', the same sort of security measures was taken during Second World War: between August 1939 and September 1945, *Lloyd's List* shipping movements were printed separately as restricted publication under the title *Confidential movements* (Barriskill, 1994); *Lloyd's Shipping Index* – formerly *Lloyd's Weekly Index* during WWI – was also a restricted publication between September 1940 and September 1945¹³. Except for war periods, special

¹⁰ Hozier H.M., Watson J.B. (1885) *Hints to Captains of the Mercantile Marine*, Glasgow: Bell and Bain, available online (<http://dbooks.bodleian.ox.ac.uk/books/PDFs/N11431452.pdf>). This kind of almanac was printed for the Corporation of Lloyd's. The authors were respectively Secretary of Lloyd's and member his office. The *Voyages Tables of Steamers* is mentioned at page 128.

¹¹ See 1918 edition of *The Newspaper Press Directory*, London: C. Mitchell and Co, available online (<https://archive.org/details/73rdnewspaperpre00londuoft>). Page 89, a note about Lloyd's Weekly Index point out: 'This paper is suspended during the war'.

¹² A sequence of 1917 German propaganda film *The Enchanted Circle (Der magische Gürtel)* give an interesting example of Lloyd's publication's use by the German Imperial Navy. This sequence show Kapitänleutnant Lothar von Arnould de la Perière (1886-1941), captain of U35, examining Lloyd's Register and writing out on it torpedoed vessels. This propaganda film, a record of a voyage by the U-35 from March to May 1917 in the Mediterranean and Eastern Atlantic, is available online at <http://www.iwm.org.uk/collections/item/object/1060008290>

¹³ A copy of Lloyd's Shipping Index issue no. 9928, dated 21 February 1945, is held by the University of Melbourne, Baillieu Library, Australia. This copy was originally registered under the no. 633, inscribed for the personal use of "Military Branch 56.S.B. 2, Admiralty, S.W.1". In 1994 edition of Barriskill's guide, there is reference to separate indexes of the movements of Vessels on Government Service, '[...] bound similarly to Lloyd's Shipping Index' (Barriskill, 1994: 17). In British Library Catalogue, *Lloyd's Shipping Index* is described as not published between 30 September 1940 and 17

instructions were printed on periodicals whose provide very specialized and sensitive information, as *Lloyd's Shipping Index*, *Voyage Supplement* or *Lloyd's Voyage Record*, restricting their use to subscribers only, requesting to destroy issues when no longer required. For researchers, consequence is that hardly any library – except for U.K. and Commonwealth – held issues of these Lloyd's periodical publications¹⁴.

Maritime network analysis based on Lloyd's publications

Among the huge corpus of Lloyd's publications, two periodicals are of a greatest significance for studying global vessel movements: *Lloyd's Shipping Index* and *Lloyd's Voyage Record*, which are two complementary sources. Tables 9.1 and 9.2 provide information about title variability, periodicity fluctuation, and numbering change for these periodicals.

Lloyd's Shipping Index was published for the first time in January 1880 under the title *The Weekly Shipping Record*. From the very beginning, the aim of *Lloyd's Shipping Index* was to provide a list of shipping movements of all merchant vessels, except Western Europe inshore and seagoing navigation (Hozier and Watson, 1885). This periodical is set practically in the same way since the 1880s. Shipping movements are indexed by vessel names in alphabetical order, with several fields of information about vessels (name, type, owner, flag, and tonnage), departing port with date, arriving port with expected date, and latest report, with geographic position and sometimes casualties. In great detail, many subfields of information evolved alongside merchant navy's progress. For example, before the Second World War, sailing vessel movements were indexed apart from those of steamers. The index is completed with the list of owners mentioned in the issue. Physical description varied over the years, with changes affecting size, and number of pages¹⁵, such an evolution being closely linked to shipping growth.

[Table 9.1 here]

Lloyd's Voyage Record was created in 1946 under the title *Lloyd's Shipping Index – Voyage supplement*. The aim of *Lloyd's Voyage Record* was to provide a list of ports of call of all merchant vessels, with some exceptions. As *Voyage Supplement*, the list concerned round voyages of vessels included in the *Lloyd's Shipping Index*. Ports of call are listed by vessel name in alphabetical order. For each vessel, the last ports of

September 1945, with a gap in issues numbering: the last 1940's issue was no. 8560 and the first published in 1945 was no. 10104. A strange fact for a suspended publication!

¹⁴ In France, according to SUDOC online catalogue (<http://www.sudoc.abes.fr>), issues of *Lloyd's Shipping Index* should be held only by the library of Ministère de la Mer. In fact, this collection had been probably pulped.

¹⁵ The number of pages varied between 64, for an issue printed in April 1890, to 200 in the 2000s. Periodicity fluctuated over time, *Lloyd's Shipping Index* being a weekly or daily publication. Each issue provides several thousands of ship movements.

call are provided with corresponding dates. Physical description also varied over the years, with changes being linked to vessels movements' evolution¹⁶. Originally a weekly publication, *Lloyd's Voyage Record* was published monthly since 1997.

[Table 9.2 here]

For both collections, the last printed publication was in 2009 before digital format replaced it. These two periodicals constitute a great source of raw data for study global vessel movements over a long period of time and at different geographical scales. Nevertheless, specific tools are required to extract and organize such raw data into a usable database.

Data extraction methodology: designing a custom optical character recognition (OCR) system

We have tens of thousands of document images derived from the digitization of hundreds of copies of *Lloyd's Shipping Index* (LSI) and *Lloyd's Voyage Record* (LVR). This set of images is an excellent source for studying world maritime trade from the late 19th century until today.

To effectively use these images, we must extract the textual content of each one in a machine-readable form (ASCII, Unicode, etc.) for use with statistical analysis software such as Excel. This text extraction process can be done manually by human operators, which has the advantage of being reliable but it is expensive, given the amount of data to be processed. A less expensive solution is to use a computer program to "read" the textual content of the document images and transcribe it into a digital format. This automated reading process is called OCR (optical character recognition).

OCR is a rather complex technology that includes several successive and complementary modules: an image preprocessing module, a structure analysis module, and a recognition module (Figure 9.1). An OCR system takes as input an image file, usually a grayscale image, which is a matrix of pixels whose values range between 0 (black) and 255 (white). At first, the preprocessing module improves the "quality" of the input image using image processing techniques such as noise reduction and contrast enhancement. This module will then make a binarisation of the image, which consists of separating the pixels belonging to the foreground (characters, separators, illustrations) from those belonging to the background. In the resulting binarised image, pixels have only two possible values: 1 (foreground) and 0 (background).

[Figure 9.1 here]

¹⁶ A weekly issue printed in December 1946 has 96 pages whereas a monthly issue in the 2000s often contained about 300.

Then the structure analysis module will determine the positions of the various blocks of textual content, separate them from illustrations, and segment them to their different physical components: headers, columns, paragraphs, etc. Each text component is then segmented to extract its different lines. Finally, the recognition module will proceed to the “reading” of the text contained in each of these text line images thanks to the combination of a recognition engine (that uses pattern recognition techniques to discriminate among the different character shapes) with a language modelling system, which models the language constraints (using a list of possible words and a statistical model of possible sequences of words). The accuracy of each of these modules affects the success of the next ones.

Because of the great diversity in the documents’ characteristics (layout, fonts, etc.), it is difficult to design systems that are generic enough to perform well on all types of documents. Accordingly, "general public" OCR software is designed to perform well on the widest possible variety of documents but its performance varies and can be very low on some atypical documents.

The tests we conducted with commercial OCR software on some samples from the Lloyd's corpus confirmed this observation. The text transcribed by this OCR system contained many errors and was not usable for reliable data analysis. It took us a long time to manually check and correct these errors before being able to use the resulting data.

In order to get better results, we decided to design a custom OCR software and to adapt it to the characteristics of our corpus to obtain the most efficient recognition and to minimise the number of errors. As a first step, we implemented a set of preprocessing operations designed to maximise recognition results on the Lloyd's images. In particular, we created two different layout analysis modules for each of the LVR and LSI documents. Each module was adapted to the specificities of the document. We also implemented a specific dewarping algorithm that corrects the distortion of the curvature of text lines that we often found on LSI documents (Figure 9.2) and a novel smearing-based text-line segmentation algorithm.

[Figure 9.2 here]

Next, we created a “recognition engine” adapted to our documents. We used an artificial neural network (ANN) to model the shapes of the characters. ANN requires prior learning on a database of image samples: a set of text line images associated with their “ground truth” text. These samples are extracted from a small subset of images randomly selected from our corpus so as to be representative of the textual content of LVR and LSI documents. Once its training is complete, the ANN is able to provide, for each line image, the most likely sequence of characters that it contains.

The last part of our work concerns language modelling, which consists first in identifying the different fields in each line (ports of departure and arrival, dates, name of vessel, type of vessel, tonnage, etc.) and then in identifying the words likely to appear in each field (Figure 9.3). Word lists thus created are used to constrain the recognition in each field: the recognition engine will only output words that appear on the list related to the current field.

[Figure 9.3 here]

This “custom” OCR system is currently still under development. Preliminary results are promising and outperform the results previously generated using a general public OCR. We are currently improving the different components of the system so as to achieve the best possible results on our document images corpus. The performance of the final system is essential to ensure the quality of statistical analysis to be performed on the data resulting from the OCR process.

Regional shifts in the global maritime network

Constructing the network

The LSI was used over the period 1890-2008 based on one entire publication every five years or so¹⁷. Global snapshots of global maritime flows only retained ports of departure and arrival as well as the number of vessel calls to construct the network where ports are nodes (vertices) and flows between them are links (edges), among other information available: dates of calls, date of construction, flag, operator, insurance registry, and gross and net tonnage. Each weekly (or daily) publication of LSI documents the last known voyage of each vessel between two or more ports, so that it represented only 0.49 percent and 0.66 percent of the respective yearly number of vessel calls for Shanghai and Rotterdam in 2008. The number of vessel calls remains a partial view of port and shipping activity, as it does not take into account the size of vessels and the value of cargo, but still, it is a good indicator of the frequency of seaborne movements. These drawbacks are compensated by a careful selection of each LSI around the same publication period, around late April, but further research is planned to make use of at least one publication every month to better avoid seasonal effects. In total, we counted 10,253 place names, of which 8,681 (85 percent) could have been retrieved directly or through intensive searches in older versions of the *Lloyd's Maritime Atlas* and online, taking into account historical

¹⁷ It must be acknowledged that the LSI excludes the movements of coasters, yachts, whalers, fishing vessels, and European vessels moving on the White Sea-Tarifa, UK-Cape Finisterre, and UK-Tarifa routes, and French and South European vessels on the way between Dunkirk, Mediterranean, and Black Sea ports.

changes of port names¹⁸. The remaining places were excluded, along with a number of passage points such as canals, straits, and channels¹⁹. Other place names such as continents, countries, seas, ranges, coasts, and regions were removed for port-level analyses but included at continent-level analyses. Vessel types were ignored in this analysis, although we calculated that steamers represented no less than 38 and 96 percent of the world fleet in 1890 and 1925, respectively (see also Ducruet, 2012).

A comparison of vessel calls with other data sources allowed us to confirm the accuracy of the Lloyd's data despite differences in collection methods and data units (Figure 9.4). Over the entire period 1890-2008, the correlation with Chinese port tonnage²⁰ is over 88 percent. This means that Lloyd's managed to capture the evolution trend of Chinese ports even though a closer look at fluctuations indicates certain discrepancies, especially for the two world war periods and the political changes of the late 1940s. However, correlation with international seaborne trade volumes²¹ is much less significant, mostly due to the non-inclusion of vessel capacity in the calculation of vessel traffic and the fact that vessels have increased in size while reducing their number of port calls. Nevertheless, the LSI is useful for looking at particular developments and at macro-structures of maritime flows, bearing in mind that vessel capacity should be extracted in future research.

[Figure 9.4 here]

The changing topological structure of the global maritime network raises important issues in terms of its underlying geography and spatial-industrial organisation (see Appendix 9.1). While the number of ports and vessels has regularly increased over time, the number of links (edges) and vessel calls has shrunk rapidly since 1990, partly because non-port locations and self-loops were excluded. But certain trends are caused by real-world phenomena. For instance, the reducing average clustering coefficient since 1946 suggests that the network has become more and more centralised; containerisation, which appeared in the late 1950s in the United States and spread globally much later, has prolonged rather than altered ongoing evolutions. A similar evolution is found with the *Gamma* index (proportion of actual links in the

¹⁸ Between 1890 and 2008, numerous ports changed names due to the political evolution of their host territory, such as Port Swettenham in Malaysia becoming Kelang or Port Klang. Different names may refer to the same port, such as Europoort (Rotterdam) or Tanjung Priok (Jakarta).

¹⁹ We calculated that the share of excluded movements oscillated between 15-20 percent until the 1970s, but increased since then up to 30-40 percent. There has been an increasing number of movements reporting only one port or linking a port with a non-port location in the more recent period.

²⁰ Chinese traffic accounts for international trade measured in Hong Kong taels for the period 1868-1928 and total port tonnage measured in metric tons for the period 1932-2010. The whole period was harmonized by Wang and Ducruet (2013) in their study of the long-term evolution of the Chinese port system.

²¹ Data was obtained from the United Nations Conference on Trade and Development (UNCTAD) for the period 1970-2008 and was completed for the 1955-1969 period thanks to Rodrigue (2015).

total maximum possible number of links) from 1920 and with the rich-club coefficient (*Gamma* index among ports with higher degree than world average divided by *Gamma* index among all ports) since 1946. The diameter and the average shortest path length have fluctuated until a rapid increase in 2000 and 2008, while eccentricity did not show any particular trend. One very interesting result is the disassortativity of the network (negative correlation between node degrees at each pair of nodes) and its decline over time, which suggests that on average, ports of dissimilar size were more connected in the past (i.e. larger to smaller), but this has faded away until present. All indicates a growing hierarchy of flows fostered by fleet modernisation and trade growth, which favoured port selection and traffic polarisation. The years 1940 and 1946 are marked by important changes, which call for further investigation into the impact of conflicts on node and network evolution in terms of route reconfiguration, network disruption, and port resilience.

Regional distribution of maritime flows

One first result is the growing share of intra- versus intercontinental maritime flows over time, from 44 percent in 1890 to 77 percent in 2008 (Figure 9.5). Such a trend based on the number of vessel calls and on large world regions, means that globalisation and the expansion of trade went along with a regionalisation of exchange. The fading out of mercantilism and colonial empires implied a reorganisation of shipping patterns, from core-periphery to a more polycentric structure between and within regionally integrated blocs. In parallel, technological evolution in the shipping and port industries provoked a concentration of flows at a smaller number of large, multifunctional port hubs and gateways, for intraregional cargo distribution, as underlined by Marnot (2005, p. 10) already in the context of the mid-1850s: “Ports had to cope with fierce competition to capture traffic that the globalising economy always made more slippery. In such a perspective, the need to provide optimal logistics [...] became the absolute rule”. The growing centralisation of the network on hub ports created an artificially high frequency of vessel trips between hub ports and feeder ports within certain regions, such as the Caribbean, the Mediterranean, and Asia. Europe and Asia stand out by their impressively higher share of intra-continental flows, which reached 84 and 86 percent, respectively, in 2008.

[Figure 9.5 here]

One second approach is to observe the changing geographic distribution of maritime flows (Figure 9.6). Europe has always been by far the world’s busiest maritime region, except in 1946 and 2008, when the leaders were North America and Asia, respectively. Such importance largely contributes to the world trend observed in the previous figure, with a sharp decline during the Second World War and during the 1970s, and peaks of maritime activity in 1965 and 1990. Despite such fluctuations, Europe in 2008 maintained its world share at around 36 percent (compared with 31

percent in 1890) whereas North America declined from 31 percent in 1890 to 7 percent in 2008, slightly below Africa. Latin America fell from 24 percent to 9 percent already between 1890 and 1920, with subsequent stabilisation at around 7 percent. Asia as a whole went through the fastest growth, from 5 percent to 41 percent over the period.

[Figure 9.6 here]

The distribution of intercontinental flows is analysed based on a synthetic diagram and maps for selected years (Figure 9.7). The evolution towards an ever more multilateral trading system can already be observed between 1890 and 1925. Trade patterns inherited from the 19th century globalisation that ends with the First World War are prolonged afterwards, as seen with the explosion of intercontinental traffic (Marnot, 2012). Transatlantic exchanges reached a peak of intensity in 1890, as seen with the triangle Europe/North America/Latin America (O'Rourke and Williamson, 1999). The bipolar link between Europe and North America underwent continuous growth since the 18th century (Guillaume, 1998), backed by strong ties between England and its former colony (Saul, 1960; Starkey, 1999). Trade between northwestern Europe and the United States represented no less than two-thirds of international exchanges in the late 19th century. While before 1890 Europe exchanged manufactured goods for US raw materials (e.g. cotton, grain, ores, fuels), the United States rapidly became the world's leading industrial country and a powerful exporter of manufactured goods to Europe, notwithstanding growing migratory flows between the two economies (Konvitz, 1994).

[Figure 9.7 here]

Yet, it was the flow between Europe and Latin America that dominated the early period, partly the result of close commercial relations between England and this part of the New World. Since the early 19th century, Latin America represented a vital provider of raw materials for the United Kingdom, which in exchange shipped manufactured goods such as cotton textiles made in Manchester, to such an extent that Latin America was often coined the informal British empire. Many countries around 1913 had high internationalisation, such as Argentina, Uruguay, Chile, Peru, Brazil, Mexico, and Venezuela (Cardoso and Pérez Brignoli, 1987). Argentina and Brazil even started to industrialise rapidly before the crisis of the 1930s²². The flow between North and South America followed a similar logic, revealing the imperialist ambitions of the United States over its backyard as seen with Theodore Roosevelt's policies, growing interest in the Panama Canal, and intervention in Cuba in 1898. Other main flows were clearly centred upon Europe throughout almost the entire period (Miller, 2012), such as with Asia and Africa, which provided mineral resources and food

²² Argentina, Brazil, Chile and Uruguay altogether concentrated 42.5% of coal shipping exports from main UK base ports to outside Europe in 1913, against 13.2% in 1920, with Argentina alone representing 20.5% and 7.1%, according to complementary data (Richardson and Hurd, 1923).

products and acquired manufactured goods. In particular, the Europe-Asia maritime route, which benefitted from declining transport costs during 1770-1830 (Solar, 2013), grew rapidly between 1890 and 1925 in the context of the British presence in the East Indies and the opening of the Far East between 1840 and 1860 and of the Suez Canal in 1869. Many Indian and Chinese ports, but also some in New Zealand and Australia, were under British rule at the time and had quasi-exclusive ties with England (Crouzet, 1964).

The rest of the period was marked by regular growth of Asia and the Pacific area as a whole at the expense of the Atlantic. This is reflected in the map by the increasing width of the Europe-Asia and Asia-North America routes. But since the 1960s, poles of the Southern Hemisphere have become increasingly connected to Asia as well. Europe remains the biggest region by the number of vessel calls and for Africa and Latin America, the latter being connected to Europe via intense and frequent vessel movements through the Mediterranean basin.

Port growth trajectories and resilience

Changing port hierarchies

Before describing the types of trajectories, it is important to highlight major shifts of port and maritime activity across the globe (Figure 9.8). The early period confirms the overwhelming dominance of two major seaboard of the industrial world: northwest Europe and the North American East Coast. In particular the so-called northern range, from Le Havre to Hamburg, clearly emerges as a vital gateway for the whole continent (Vigarié, 1964; 1998) between 1890 and 1920 at the expense of British ports, whose growth rates fell behind those of Antwerp and Rotterdam. Germany, with its main ports of Bremen and Hamburg, was then becoming the world's second-largest industrial power and an important gateway between Eastern Europe and the United States for immigration which, in turn, positively influenced rapid port growth in the Benelux for transit trade. This shift of Europe's centre of gravity was also influenced by a strong pound sterling during the 1920s, which hampered British industries. Another significant change was the emergence of the Soviet Union and the rapid growth of Baltic and Black Sea ports. A similar trend occurred along the northeastern seaboard of the United States, the megalopolis in the making (Gottmann, 1961), where New York was the core gateway of US external trade and the world's premier port for European immigrants, but whose supremacy was challenged by Boston and Baltimore in the late 1890s (Heffer, 1986).

[Figure 9.8 here]

One unexpected giant in the global port hierarchy was Buenos Aires, followed by other River Plate ports such as Montevideo and Rosario. By the number of vessel

calls, Buenos Aires was the world's largest port in 1890, the main port of Latin America's most dynamic port region at the time (Barjot, 2006). Rio de Janeiro also exhibited rapid growth as it was fully modernised already in 1904. On the Pacific coast of Latin America, however, Valparaiso (Chile) and Callao (Peru), once large exporters of raw materials (copper, nitrates, guano) and intermediate hub ports between North and South America, lost ground, in part because of the opening of the Panama Canal in 1914. Elsewhere, the most impressive growth was in the Asia-Pacific region, as seen with the extremely high growth rates of certain Japanese and Australian ports, while Chinese ports suffered from internal wars and political and economic tensions (see also Figure 9.4). By contrast, Japan's growth illustrates its successful entry into the small group of world industrial powers. It sustained strong ties with North America's West Coast, as the United States ensured more than 40 percent of Japan's external trade in the mid-1920s. To be noted is the shift from San Francisco to Los Angeles and Seattle-Vancouver. Other factors include Japan's imperialist strategy over the entire Asia-Pacific rim, which gave a boost to certain ports such as Vladivostok in Russia and Dalian in China. Asia as a whole benefitted from the acceleration of maritime trade through the Suez Canal, where steamers concentrated their activity (Piquet, 2009). But sailing vessels maintained an important share along certain routes for technical and economic reasons, such as across the Pacific Ocean with the windjammers, the last generation of clippers, which specialised in bulk cargoes (Fletcher, 1958; Lehnof, 2007).

The rest of the period was marked by a continuous concentration of vessel traffic within Asia around the large hub ports of Hong Kong and Singapore, which captured most transshipment activities at the expense of Japan (Lee and Ducruet, 2009). The demise of the British Empire caused the decline of Calcutta and Mumbai, once Asia's largest ports, while Hong Kong and Singapore, together with Taiwan and South Korea, emerged as newly industrialised countries since the 1960s. The spread of this export-oriented development strategy to Southeast Asia and China as well as the rise of new container hubs along the Europe-Asia maritime route such as Dubai and Colombo occurred in parallel with the slowdown of many other traditional Asian port cities (Ducruet, 2015). Singapore is nowadays the world's largest port by the number of vessel calls, and the second largest after Shanghai. Yet, as seen in appendix 9.2, Shanghai's growth over the period had been anything but linear, as it had difficulty restarting its activity after the radical political changes of the late 1940s. London, Buenos Aires, and New York showed continual decline. With the exception of the 1946 peak due to the post-war revival, most leading ports went through rather complex traffic fluctuations based on a mixture of local and global factors.

A typology of port growth trajectories

In order to highlight growth similarities over space and time, a correspondence analysis was applied to the distribution of betweenness centrality among 169 ports which recorded uninterrupted activity over the period under study. One main

hypothesis of this work is the influence of geographic proximity, in addition to other proximities (cultural, logistical, and political) on the nature and spatial distribution of the obtained clusters. The coordinates of ports on the orthogonal components and their weight allowed us to generate a matrix of traffic discrepancies (measured using a χ^2 distance). A hierarchical cluster analysis was applied to this matrix using the Ward method, which minimises intra-class variance and maximises inter-class variance. This method, using Trajpop freeware²³, was recently applied to urban population time series in various economies (Pumain et al., 2015), and closely echoes work by Guerrero and Rodrigue (2014) based on port container throughputs in 1970-2010. The latter work identified five diffusion waves of containerization and their representative ports, from the pioneers of the Triade to the niche ports. Compared with these works, one major innovation of our research is to use a network centrality measure rather than traffic volume. Betweenness centrality being a fundamental indicator of global accessibility, it carries crucial information about nodes' ability to be situated on shortest paths all over the network, and to act as bridges (or hubs) between the different regions of the network. Because the number of occurrences on shortest paths depends on the size of the graph, it was decided to transform, for each port, each yearly score into a percentage of the maximum value of the period.

Six clusters were found to have a relatively balanced number of ports. Three are marked by overall decline and the three others by overall growth. The first cluster is marked by rapid decline and intense fluctuation of formerly dominant ports but without recovery afterwards: Montevideo, Rosario, Bridgetown and Saint Thomas in Latin America; Cadiz, Falmouth and Plymouth in Europe; and Port Elizabeth and Port Louis in southern Africa. Once well inserted into important Atlantic trading routes, these ports were not able to sustain their position in the network. The second cluster went through a similar evolution but with a decline from the 1950s onwards following a peak of centrality in the 1920s. Interestingly, the vast majority of these ports are located in the North Atlantic region; they include New York and Boston in North America; most British ports (Glasgow, Leith, Tyne, Hull, Liverpool, London, Swansea, Cardiff, and Newport), and Marseilles, Bordeaux, and Bergen in Europe. The two exceptions of Oran (Algeria) and Yangon (Myanmar) can be explained by the colonial factor, as their centrality closely overlapped with those of their European counterparts. The third cluster, whose ports have declined in centrality less rapidly than the two former clusters, is more widespread geographically. It is concentrated mainly in Scandinavia (Copenhagen, Gothenburg, Oslo, Kristiansand, Stockholm, Helsinki), the United Kingdom (Grangemouth, Bristol, Grimsby, Goole), North America (Halifax, Philadelphia, Baltimore, Hampton Roads, San Francisco, Houston), Latin America (Recife, Buenos Aires, Talcahuano), and the Asia-Pacific (Calcutta, Manila, Sydney, Melbourne, Adelaide). The progressive shift from the Atlantic to the Pacific, the end of colonial rule, and the centralisation of maritime flows in large hub ports tended to push these ports from the network's centre of gravity.

²³ <http://trajpop.parisgeo.cnrs.fr/>

The other three clusters had different ways of increasing their centrality over time, though they shared certain similarities. The fourth cluster tended to lose centrality up to the 1950s, followed by recovery and stabilisation until the mid-1990s. In Europe this was the case of Antwerp, Rotterdam, Bilbao, Las Palmas, Piraeus, and Odessa. Elsewhere, Alexandria, Vancouver, New Orleans, Rio de Janeiro, Mumbai, Perth, Jakarta, Bangkok, Hong Kong, Kobe, and Yokohama are still important ports today, but they are challenged by competition from close neighbours. The fifth cluster has in common with the former that it ceased to grow in centrality during the late period, but showed continuous improvement until then. Most of these ports are European (Le Havre, Rouen, Bremen, Hamburg, Szczecin, Gdansk, Genoa, Trieste, Naples, Leixoes, Lisbon) or African (Algiers, Casablanca, Tunis, Dakar, Cape Town, Maputo), plus Havana (Cuba) and Brisbane (Australia). Finally, the last cluster exhibited stability until the 1950s and rapid growth since then, with Shanghai and Singapore as the top central ports on average, followed by Durban, Santos, Barcelona, Valencia, Port of Spain, Willemstad, Callao, and Valparaiso. This cluster has shifted its centrality from the bottom to the top over the period, reflecting the dynamism of their host economies (BRICS countries), the impact of port reform (Spain), and the development of hub functions (Caribbean).

Impacts of crises and shocks on port traffic and network topology

Since a maritime link is defined by the flow of goods, and given the trade importance of shipping (see Chapter 17 by Guerrero et al. on global trade and shipping) it is subject to changing economic and political conditions. Supply and demand, in addition to geographic and cost factors (e.g. fuel prices), combine with specific events or shocks such as financial crisis, wars, and embargo to modify the intensity and spatial structure of maritime flows. In a historical perspective, how does the topology of maritime networks respond to such shocks? Do shocks of similar nature have comparable effects on port nodes and network topology?

Further research is needed to classify shocks by their nature and scope in order to ensure some measure of comparability: economic, political, geographic, and technological. The first two categories are self-explanatory. The latter two may refer to natural disasters or to the opening and closure of critical choke points. Opening (or expanding) an interoceanic canal shortens nautical distance between certain ports, which in turn may reduce average transport costs, while its closure has opposite effects at various levels. For instance, the closure of the Suez Canal in 1967 (Six-Day War) modified the European port hierarchy due to an increase in ship size but at the same time it favoured economies of scale on the Europe-Asia route around the Cape of Good Hope (Cullinane et al., 2010). Shocks related to innovation and technological change directly impact transport costs by making ships or cargo handling more reliable, efficient, and faster (Rodrigue, 2013; Bernhofen et al., 2013). The case of the Suez Canal closure was geographic, political, and local in scope as it directly affected only one node. Its opening was a mixture of geographic and technological elements in

terms of rerouting and nodality. One may distinguish among local shocks, which directly affect one or few nodes, regional shocks, which are greater in scope, and symmetric shocks, which hit distant nodes simultaneously, such as in the case of an oil price shock, especially for oil tanker movements. Though data extraction from *Lloyd's List* is still in its infant stage, Appendix 9.2 already points at interesting similarities among world ports in terms of the traffic impact of war destruction (Hamburg, Rotterdam, Tokyo) and political revolution (Shanghai) for instance. A thinner time granularity is needed to zoom on specific events, however (see Chapter 10 by Guinand and Pigné on dynamic graphs). This would allow, among other cases, to compare, for instance, the impacts of the 2008 financial crisis (De Monie et al., 2011) with the ones of the 1929 Black Friday.

Yet, related literature remains limited when it comes to measuring the impact of shocks on maritime networks. International organisations and maritime industries devoted much attention to security issues against terrorist attacks on ships and ports (Bichou, 2008; Ciotti, 2009). Some studies quantified the costs of a shock mainly for ports being directly affected and not for others. Rosoff and von Winterfeldt (2007) estimated that a terrorist attack on the largest US ports (Los Angeles and Long Beach) would lead to a 120 to 365-day port shutdown and would roughly cost 30-100 US\$ billion in port, evacuation, property value, and decontamination costs. A similar study by Booz Allen Hamilton Consulting proposed a port security disaster war game to assess network impacts of a terrorist attack on a US port, resulting in a 12-day closure of the US ports and borders, 58 US\$ billion of economic losses, and a 3-months backlog to clear (Garencser et al., 2003). Paul and Maloni (2010) adopted a more theoretical approach about the effects of US port lockout due to different types of shocks (strikes, hurricanes). Their model about the dynamic ship rerouting helped minimising congestion and economic losses in North America.

While most of the existing literature focuses on estimating losses for the local economy or on a theoretical situation, the World Seastems project aims to study changes in global network topology resulting from historical shocks. These studies will be complemented by analyses of shock propagation mechanisms and long-term effects of the shocks in question. As discussed in Chapter 13, several possible approaches and methodological frameworks exist in graph theory and complexity science, such as the model of cascading failures. Given the specific character of different fleets, a multilayer perspective seems necessary (De Domenico 2013; Ducruet, 2013b), to reveal heterogeneity in responses to shocks of different subnetworks built by types of ships.

Conclusion

This first-ever systematic analysis of the *Lloyd's List* corpus over nearly 120 years provides novel evidence about the macro-level organisation of global maritime flows and their local dynamics. It has confirmed drastic shifts of maritime activity from the Atlantic to the Pacific reflected in the changing pattern of both intercontinental flows

and port hierarchies. One innovation was to identify Buenos Aires as the world's largest port by the number of calls in 1890 surpassing London and New York. Yet, port growth trajectories are very diverse and marked by short-term events. In terms of network structure and evolution, this chapter also contributes to the reflection on graph dynamics by highlighting long-term trends and questioning the role of technological progress. Although it would be necessary to decouple the database and compare network topologies for different fleet types, our results show that network centralisation started long before the age of containers, in line with Marnot (2005) about 19th century port competition. Much more has to be done in several directions: extraction of more data to fully cover the period on a weekly or monthly basis, in-depth analysis of local and global shocks and crises, and retro-simulation of past network structures to allow forecasting.

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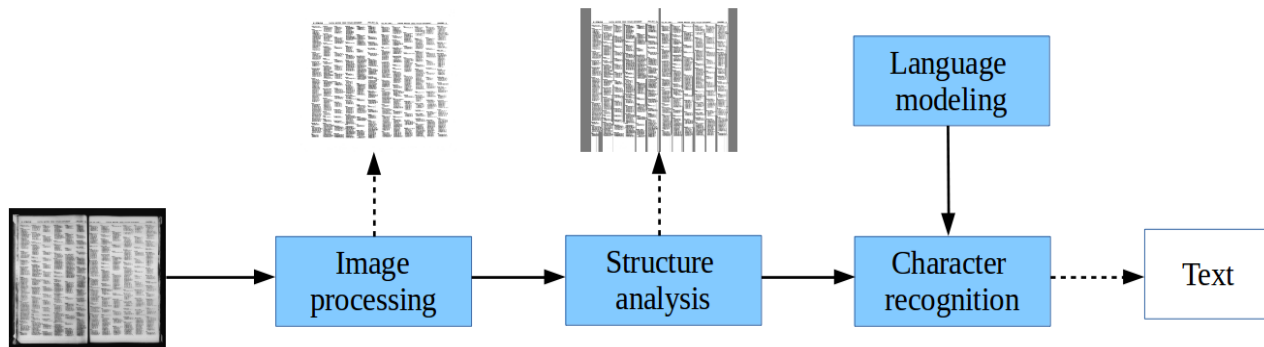


Figure 9.1: Illustration of the processing chain of an OCR system

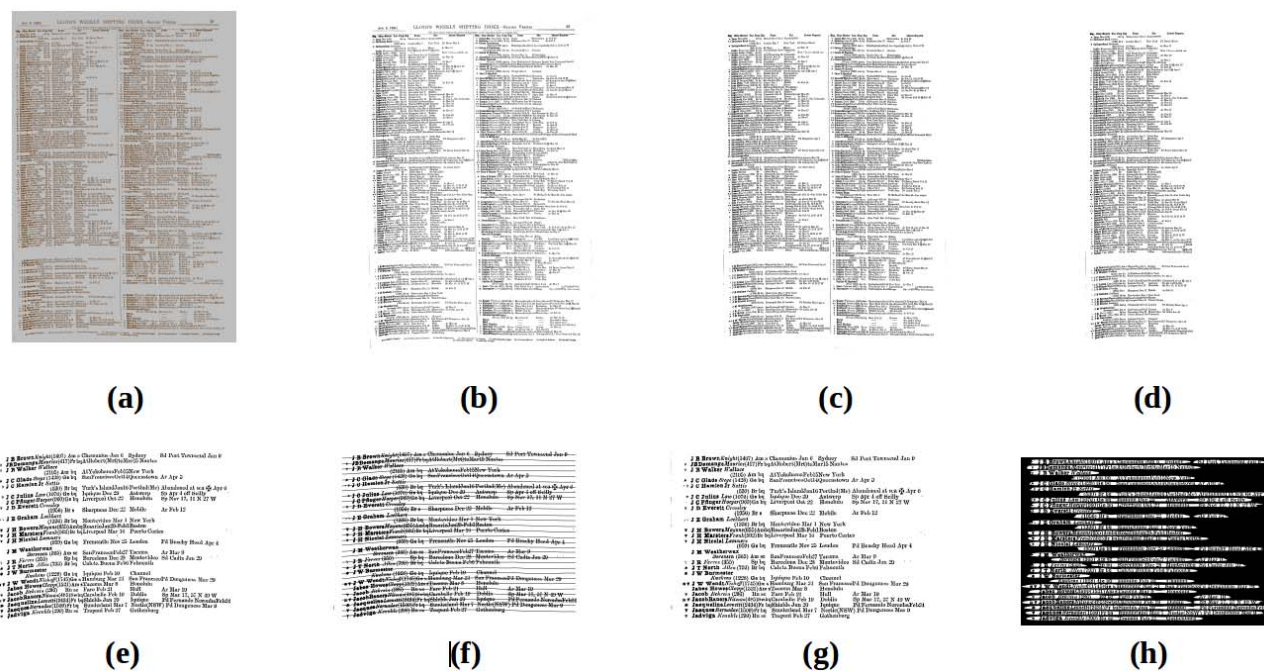


Figure 9.2: Illustration of the processing steps on a sample of the LSI dataset
 (a) Original grayscale image. (b) Binarized image. (c) Header and footer removal. (d) Segmentation in columns (left column). (e) Part of the left column. (f) Lines curvature estimation. (g) Correction of lines curvature (dewarping). (h) Detection of text lines borders.

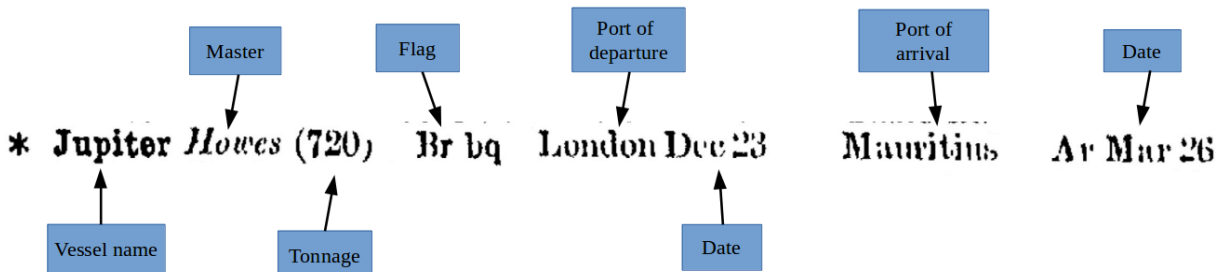


Figure 9.3: Constitutive fields of a text line from a LSI document

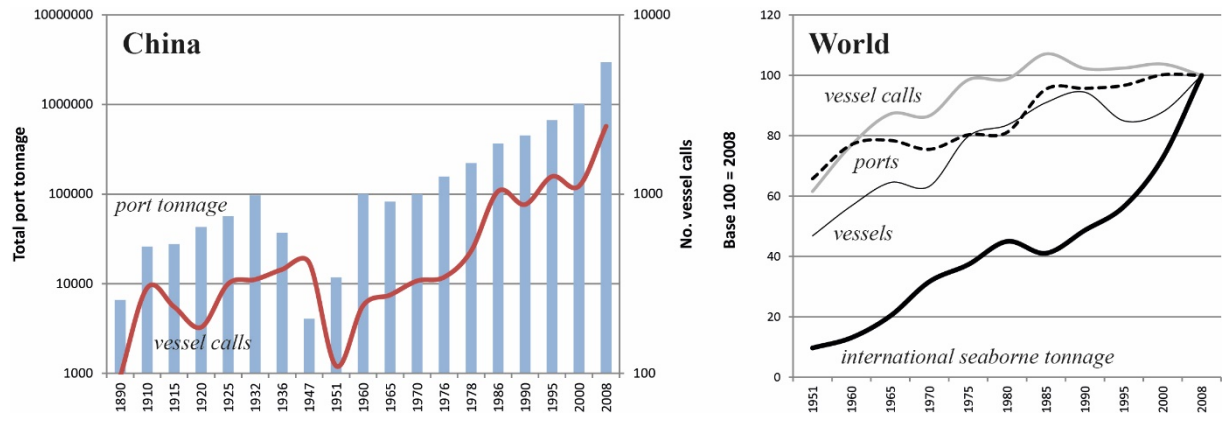


Figure 9.4: Comparing traffic evolution from diverse sources

Source: own realization based on Lloyd's Shipping Index, UNCTAD and World Bank

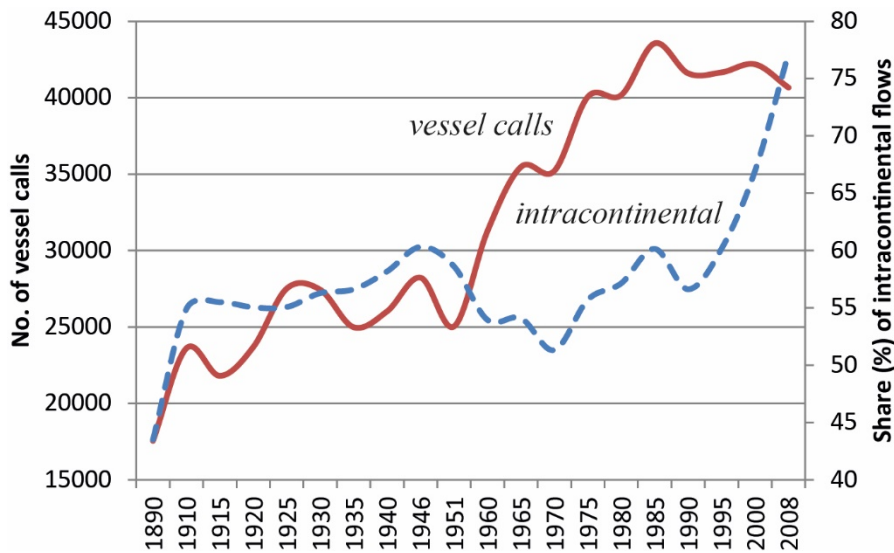


Figure 9.5: Total versus intracontinental vessel flows, 1890-2008

Source: own realization based on Lloyd's Shipping Index, various issues

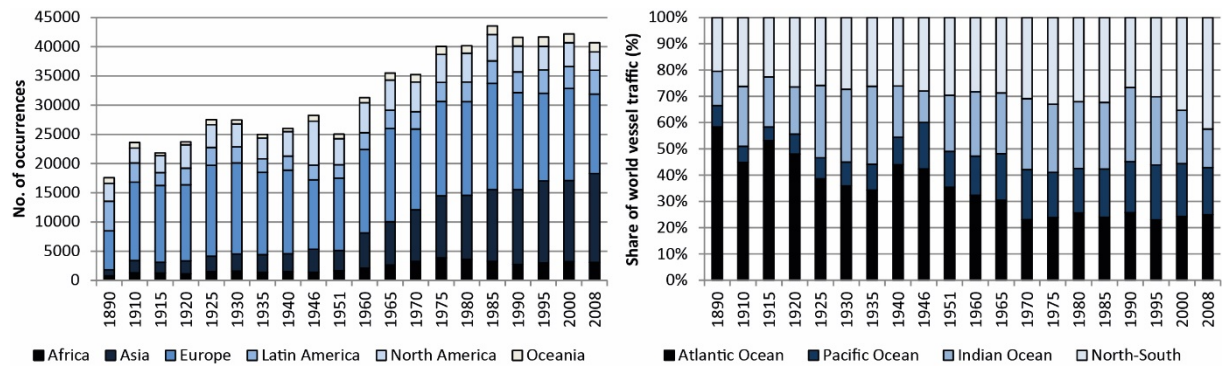


Figure 9.6: Regional distribution of world maritime flows, 1890-2008

Source: own realization based on Lloyd's Shipping Index, various issues

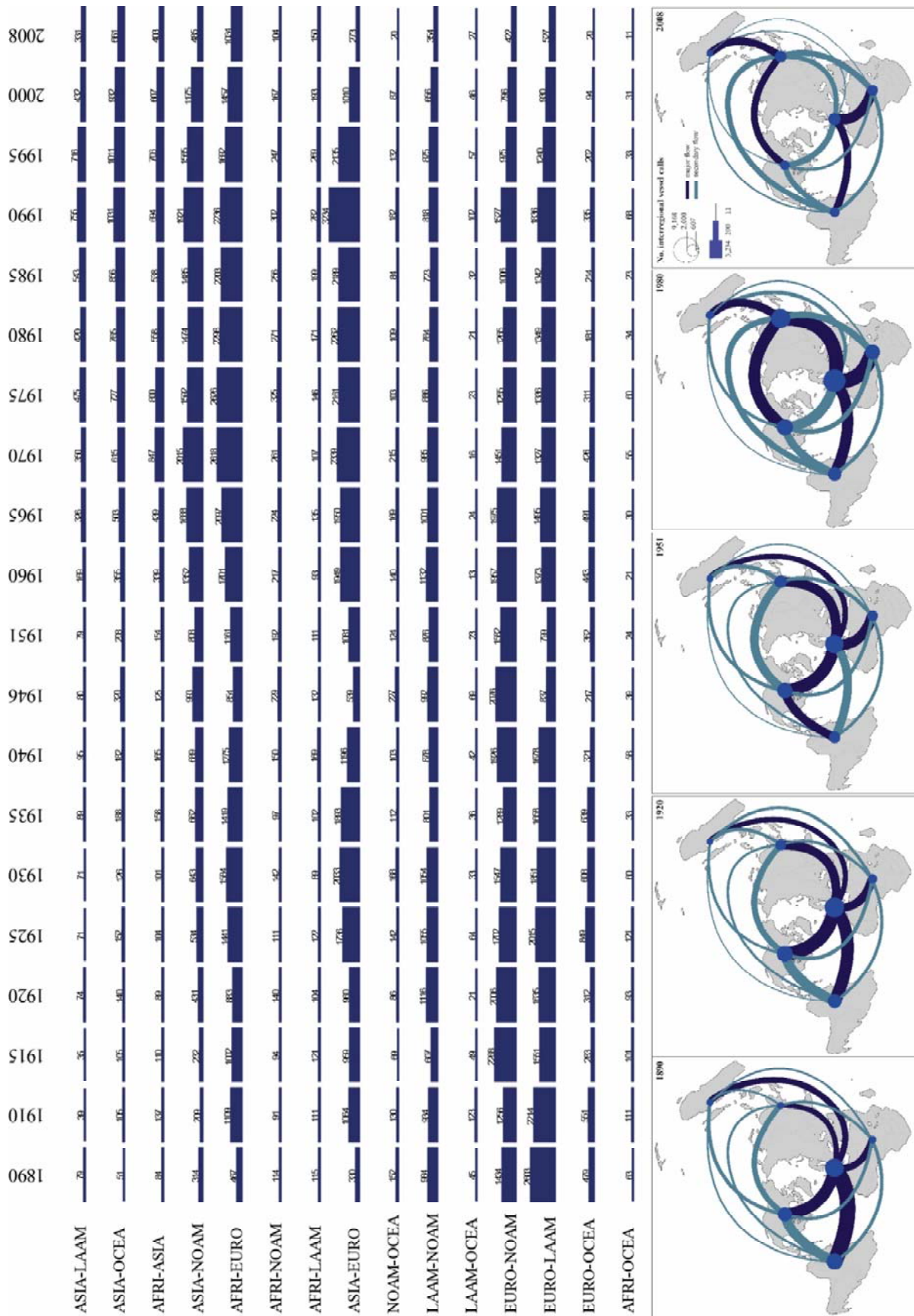


Figure 9.7: Intercontinental maritime flows, 1890-2008

Source: own realization based on Lloyd's Shipping Index, various issues

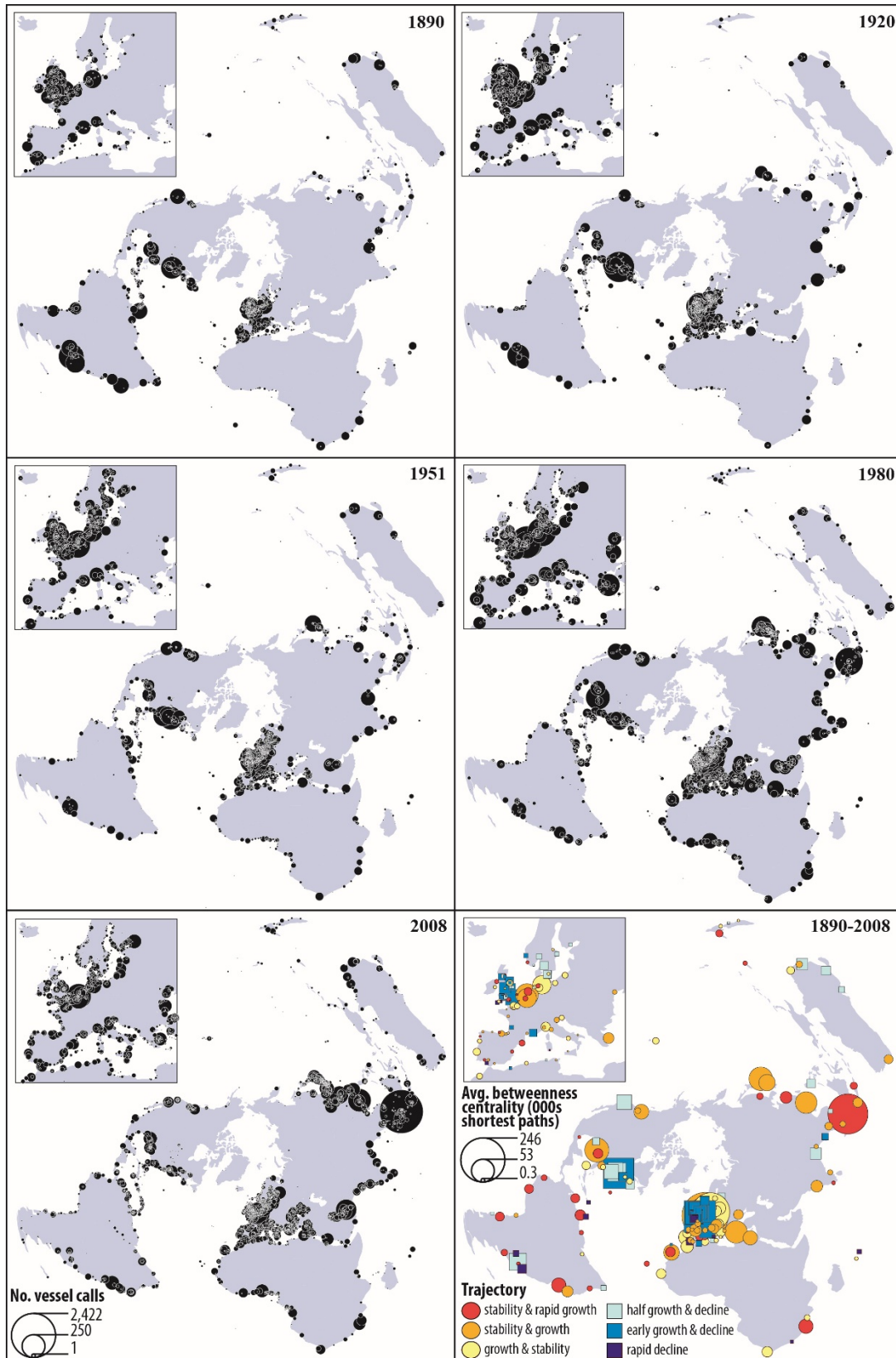
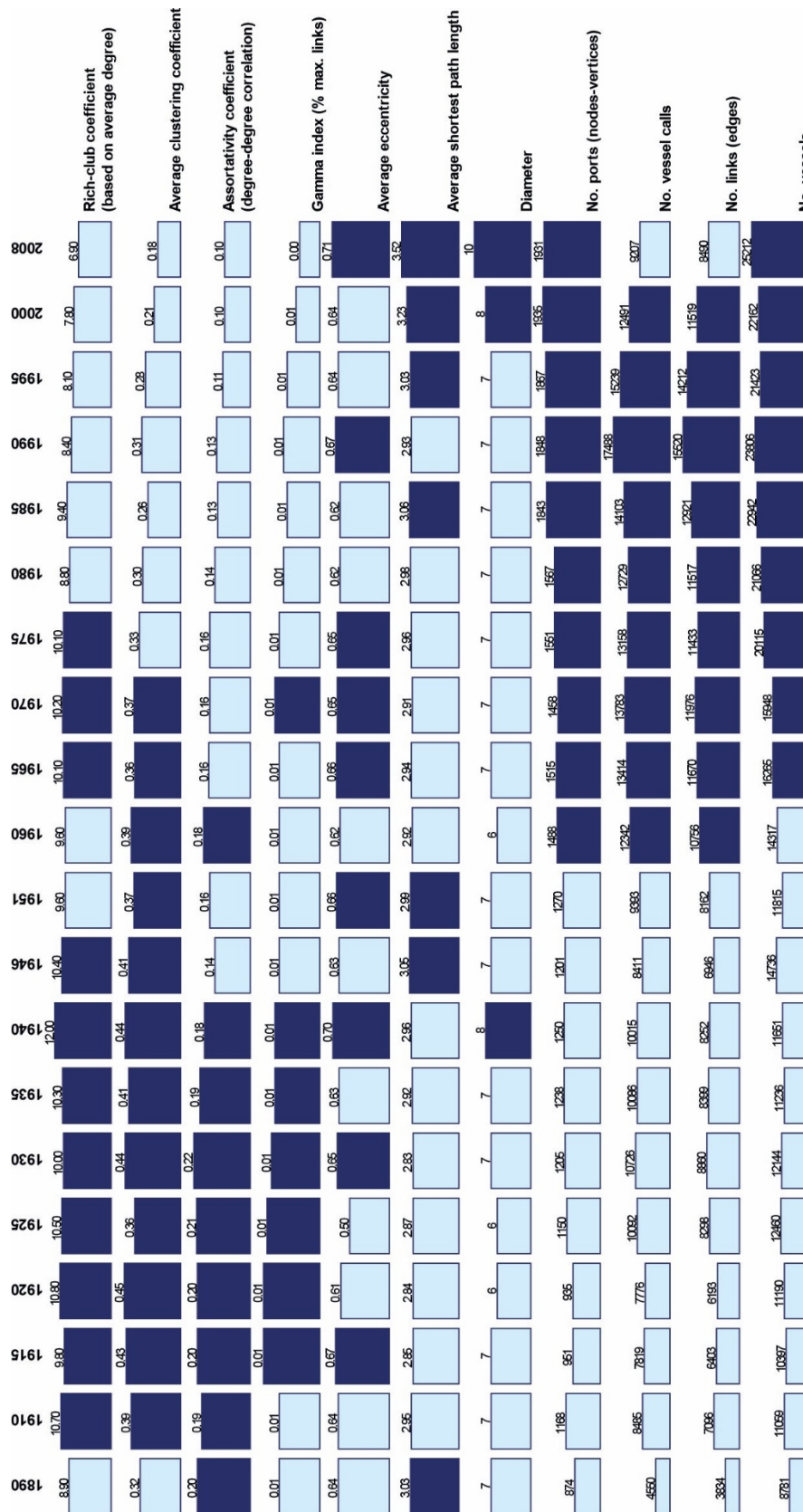
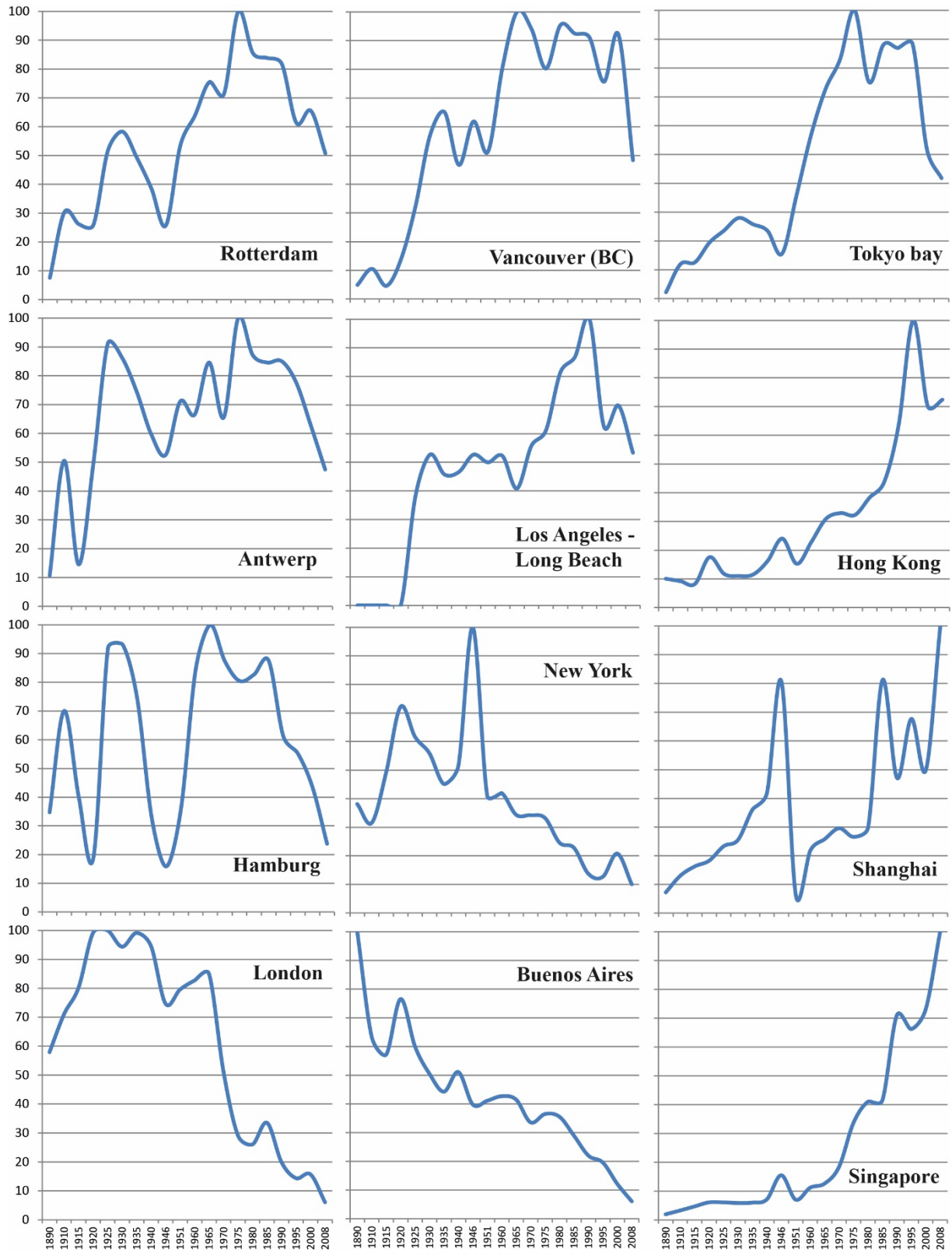


Figure 9.8: Port hierarchy evolution and typology of port betweenness trajectory, 1890-2008

Source: own realization based on Lloyd's Shipping Index, various issues



Appendix 9.1: Graph topology of the global maritime network, 1890-2008
 N.B. bold colors refer to values higher than row's average; assortativity appears in positive (opposite) values for simplicity



Appendix 9.2: Vessel traffic evolution at selected world ports, 1890-2008

Source: own realization based on Lloyd's Shipping Index, various issues

N.B. base 100 for the maximum value of vessel calls

Years	Title	Issues	Note
1880	The Weekly Shipping Record	1	1 Jan.1880
1880-1914	Lloyd's Weekly Shipping Index	2-1880	9 Jan.1880 - 25 June 1914
1914-1917	Lloyd's Weekly Index	1801-1947	3 July 1914 - 19 April 1917
1917-1918	Not published between 19 April 1917 and 2 Dec.1918		
1918-1932	Lloyd's Daily Index	1948-6014	2 Dec.1918 - 13 May 1932
1932-1936	Lloyd's Daily Shipping Index	6015-7142	17 May 1932 - 1 Feb.1936
1936-1940	Lloyd's Shipping Index	7143-8560	3 Feb. 1936 - 30 Sept.1940
1940-1945	Lloyd's Shipping Index	8561-10103	Restricted publication between 30 Sept. 1940 and 17 Sept. 1945
1945-2009	Lloyd's Shipping Index	10104- ?	17 Sept.1945- December 2009?

Table 9.1: Evolution of the Lloyd's Shipping Index, 1880-2009

Years	Title	Issues	Note
1946-1972	Lloyd's Shipping Index - Voyage Supplement	Numbering identical to LSI; only date of publication last years	Nov 1946-April 1972
1972-2009	Lloyd's Voyage Record	1-?	April 1972-May 2009?

Table 9.2: Lloyd's Voyage Record, 1946-2009