A systematic and critical review of port system research

César Ducruet, Theo E. Notteboom

A systematic and critical review of port system research

César Ducruet[1] and Theo Notteboom[2]

This is the draft version of the book chapter published in: Ducruet C., Notteboom T.E. (2023) (Eds.), *Port Systems in Global Competition. Spatial-Economic Perspectives on the Co-Development of Seaports*. London & New York: Routledge Studies in Transport Analysis, pp. 13-54.

Abstract

Despite its wide use in port studies, the concept of port system remains relatively vague and ill-defined, ranging from a geographic or administrative area containing two or more ports to an interconnected set of port nodes in a given network. Based on a corpus of no less than 268 articles, this chapter investigates how port systems have been studied since the pioneer works of the 1960s. The bibliometric approach underlines a growing publication trend and collaboration dynamic over time, a shift from geography to transport journals, and a widening focus from national to transnational and global. The content analysis reveals that although more than half of the corpus concerns issues of concentration/de-concentration, new concepts are emerging in port system studies, which underline different spatial patterns and processes. To be noticed is the growing importance of maritime connectivity, after decades of dominant land-based models focusing on hinterlands.

Keywords: connectivity; foreland; hinterland; port system; spatial pattern

Introduction: emergence and diffusion of the port system concept

The concept of system is very popular in both natural and social sciences, but its meaning differs greatly across the academic spectrum. Yet, it is commonly accepted that systems are sets of interactions forming a totality, while being more or less resilient, balanced, and self-organized (Sanders, 2005). In geography, a spatial system is open, through relations with its environment (Pumain, 2004). Related issues concern the conditions of its emergence (systemogenesis), its evolution (resilience, bifurcations), interactions among subsystems (self-organization) as well as top-down or multilevel interactions. Systems may emerge at all geographic scales, such as the world system, urban or regional system, and local productive systems. The *general systems theory* developed by Bertalanffy (1950) considered that a system is greater than the sum of its parts – an idea already developed by eminent scholars such as Aristotle, Confucius, Avicenna, and Pascal. This is

[1] French National Centre for Scientific Research (CNRS), UMR 7235 EconomiX, France. Contact author: cesar.ducruet@economix.fr
[2] Antwerp University & University of Ghent, Belgium.

due to synergy effects and emergent behavior among the parts, which foster new qualities or properties. Each part can also be a system on its own, as proposed by Berry (1964) when considering "cities as systems within systems of cities".

Port studies, by their principal focus on single ports, developed in relative isolation from mainstream research on systems. Systemic thinking emerged relatively soon in port geography, however. In Northwest Europe, Pounds (1947) identified a "normal pattern of relationship" between upstream (port) and downstream (outport). He summarized the emergence of outports by four main factors: (1) silting of estuaries and lower courses of rivers, (2) increasing size of vessels, (3) *ports de vitesse* (passenger transshipment at optimal locations), and (4) time and cost of navigating the estuary. The spatial model *Anyport* was proposed by Bird (1963) based on similar dynamics taking place at British estuaries. The shift of port facilities from upstream port city to downstream deep-sea locations was verified in various parts of the world by other geographers. Other spatial models or "chorotypes" of the estuary were proposed, highlighting the complementarity between upstream and downstream port cities (see Brunet, 1990; Brocard et al., 1995).

Two major contributions enlarged the focus from two ports to multiple ports. An ideal-typical sequence of transport system development was proposed by Taaffe et al. (1963) based on the cases of Ghana and Nigeria. In addition to the emergence of inland transport corridors, the spatial model and related cartographies particularly insisted on the process of port concentration within each country over successive phases. The transnational perspective was provided by Vigarié (1964) in his book on the major trading ports from the Seine to the Rhine. His historical analysis at the level of the whole maritime range also pointed to a concentration process, at the advantage of the Benelux, in a context of expanding hinterlands and ongoing European integration. One originality of Vigarié's work had been to consider forelands in addition to the port itself and to hinterlands as a factor of port competitiveness. The importance of maritime linkages motivated Rimmer (1967a, 1967b) to update the ideal-typical sequence of Taaffe et al. (1963) and apply his new spatial model to Australia and New Zealand, although the added maritime linkages did not account for the whole foreland of ports.

It is only one year later that the concept of port system emerged explicitly in the literature, from a maritime perspective. Robinson's (1968) PhD on British Columbia ports constitutes the first-ever empirical analysis of a shipping network using graph theory, with multiple references to port geography and regional science. He proposed that "*the system of ports operating interdependently may now be regarded in abstract form as a set of points or nodes in a network, a transportation network in which the lines or links are in fact 'imaginary' routes traced out by foreign trade shipping*". For the first time, ports were compared by their connectivity (degree centrality) and nodal importance (hub function, or focal ports) rather than their tonnage. A port network development model was also added.

The next work of Robinson (1976) was thought as a bridge between operations research and regional science. The author proposed a new spatial model including five geographical scales: (1) intra-port or single element system (e.g., inter-berth movements), (2) port-hinterland system, (3) two-element port system (shipping network), (4) regional port system (several ports along a coastline), and (5) N-port system (the "total" system with its hinterlands and overseas linkages). Ship turnaround time was considered to be the core indicator of the system's wealth, as "*Inefficiency within the port (…) will* *eventually restructure the basic spatial patterns (…) of existing facilities [and] lead, of course, to spatial restructuring at an interport scale*".

The works of Robinson did not have much followers, as subsequent studies primarily focused on the coastline and its hinterland. The lack of shipping data, and the fact that his PhD had never been published partly explain this state of affairs. A few years later, Vigarié (1979) proposed a parent model, the port triptych, whereby ports connect forelands and hinterlands, but it was not accompanied by a proper methodology. Other generalizations mainly consisted in updating the landward-looking model of Taaffe et al. (1963), by documenting the influence of containerization on the concentration (Hayuth, 1981) or de-concentration (Hayuth, 1988) of port systems, especially in North America. Examples from all over the world were proposed in the seminal book of Hoyle and Hilling (1984) on *Seaport Systems and Spatial Change*.

As a consequence, "*only a few theories exist on the development of a container port system in relation to forelands, hinterlands and the technological environment*" (Notteboom, 1997). Despite the relatively sheer number of publications on the spatial analysis of ports (Pallis et al., 2011) and port systems (Ducruet et al., 2009), "*the analysis of port systems remained virtually unchanged since the 1980s*" according to Pallis et al. (2011). Yet, Woo et al. (2011) considered spatial analysis and especially the "Hayuth model" to provide "*relatively stronger theoretic bases than other research theme categories*", although being "*purely geography-based*". Other reviews of port research were proposed, giving more or less importance to the port system theme. When visualizing title words' co-occurrences within a corpus of papers about container shipping, Lau et al. (2017) only found a tiny link between "port system" and "ports" for the period 1999-2013. Among keywords associated with "port", the term "system" did not appear among the top ranked ones in Chen et al. (2018), compared with port performance, state control, governance, choice, competition, and privatization. Munim and Saeed (2019) did not even identify port system as a co-occurrence, compared with port choice, hierarchy, cooperation, among others. It was also absent from the review of Wang and Peng (2021), which better underlined the importance of port simulation, location, hinterland, service, allocation, policy, and integration.

Important questions thus arise: how has the literature on port systems evolved internally and in relation with wider academic research? Is the concept of port system still relevant today in geography and elsewhere to study ports? The literature on port systems has never been systematically reviewed. Previous attempts looked at one facet only, such as concentration and de-concentration dynamics (Ducruet et al., 2009), the evolution of port geography since the 1950s (Ng and Ducruet, 2014), and the delineation of port systems (Ducruet and Notteboom, 2022). Interestingly, Ng and Ducruet (2014) as well as Ducruet et al. (2019) classified port system papers in a category distinct from "port connectedness", "port choice, competition and cooperation", and "port's place in shipping strategies and networks", while the delineations proposed by Ducruet and Notteboom (2022) were only based on the design of shipping networks. This echoes in some way the old debate between hinterland and foreland, and is partly caused by the absence of a commonly accepted definition of the port system.

In this chapter, we analyze a corpus of more than 260 articles about port systems, published between the 1960s and 2022. The methodology of corpus construction is presented in the next section, together with an analysis of the main publication trends. It is followed by a classification of main research subthemes. In particular, we attempt to verify the extent to which port system research constitutes a relatively unified research field, and whether it innovates compared with its anchoring in spatial models. Further research pathways are discussed in conclusion.

The corpus of port system studies

A search in Google Scholar dated 15th August 2022 was performed in two successive steps. First, we selected any journal article explicitly mentioning "port system" in its title and/or abstract, including variants such as seaport system, inter-port system, multi-port system, or seaport-dry port system. The pioneering works on port systems, which did not use these expressions (Taaffe et al., 1963; Rimmer, 1967a, 1967b; Hayuth, 1981, 1988), were included in the corpus. We also included all articles not explicitly mentioning "port system" but citing these models, and dealing with ports.

A total of 268 articles have been identified, comprising of 169 articles explicitly mentioning the notion of "port system" and 99 articles referring to port system models (see **Appendix 1.1**). Several interesting trends can be observed in **Figure 1.1**. The total number of articles remained relatively modest during the early period, followed by rapid growth from the early or mid-2000s. Port system research is thus a relatively buoyant field today. Considering each sub-category, articles explicitly mentioning "port system" have always been dominant in number, except for a few years. This means that the concept of port system gained popularity over time, but also that the original models never ceased to influence new research.

[Insert Figure 1.1 about here]

Figure 1.2 underlines that the share of geography journals declined continuously over time, compared with transport and other journals. Such an evolution recalls the findings of Ng and Ducruet (2014) about port geography in general. They observed that geographers themselves increasingly published in transport journals: "*port geography has gradually drifted away from actively participating in the philosophical discussions within human geography*". Between 2020 and 2022, only 7 papers were published in geography journals, against 34 in transport journals and 10 in other journals. However, the ratio between the share of authors being geographers and the share of geography journals has always been over 1, for the reasons mentioned above, in the 1980s (1.86), 1990s (1.56), 2000s (1.59), 2010s (1.58), and 2020s (2.00). **Figure 1.2** also reveals a diffusion of the concept of port system from geography to transport and other fields, in parallel with the growing absolute number of publications.

Table 1.1 presents the journals having contributed the most to port system research. While Journal of Transport Geography is both a geography and a transport journal, five "general geography" journals belong to this list: Geojournal, TESG, Environment and Planning A, Economic Geography, and Chinese Geographical Science. Among the top transport journals are maritime journals, with Maritime Policy and Management and Maritime Economics & Logistics claiming a dominating role, followed by Marine Policy and Journal of Maritime Research. The rest of the journals are "general transport" journals.

[Insert Figure 1.2 about here]

[Insert Table 1.1 about here]

Research trends in port system studies

Concentration and de-concentration factors

Three main approaches to hierarchical phenomena can be distinguished in **Table 1.2**, which condenses no less than one-third of the whole corpus. The first one, essentially quantitative, investigates whether port traffic distribution reflects the successive phases of concentration and de-concentration of port system evolutionary models. Such studies apply a variety of measures to traffic time series, such as concentration ratio, Gini coefficient, and Herfindahl–Hirschman index for the most popular. Hilling (1977) has been the first scholar, to our knowledge, to employ concentration ratios. The work of Notteboom (1997) and its updates (Notteboom, 2006, 2010, 2016) on the European and other port systems worldwide reinvigorated such an approach. The early adoption of new technologies such as steam, containerization, and intermodalism (see the review by Ducruet and Itoh, 2022), and a large market size (city, hinterland) were often recognized to benefit port concentration, and the development of the “periphery” (e.g., new port development, traffic shifts) at the expense of the “core” (e.g., lack of space in large load centers, handling costs, congestion) as a factor of de-concentration, in line with the models.

The second approach, also quantitative, is a search for “laws” or “mechanics” ruling the structure and/or evolution of a large sample of ports. For instance, it was demonstrated that the largest ports are also the most diversified (Charlier, 1988; Ducruet, 2017, 2022), although smaller ports may also have a wide commodity portofolio, when hosted by large cities, benefiting from a captive hinterland, and locating at the periphery (Ducruet et al., 2010). In the same vein, Ducruet (2020) verified the applicability of scaling laws to ports, showing that the largest cities concentrate the most valuable traffic (containers, general cargo). The rank-size distribution (or Zipf’s law) of port throughput served to scrutinize hierarchical tendencies, as in the case of China (Xu et al., 2021; Li et al., 2022) and at the global scale (de Oliveira et al., 2021). The originality of the latter work is to complement the rank-size analysis by a look at the intra-distributional mobility of ports: “*Markov chains aim to explore the extent to which ports move between groups of large, medium or small size units*”. The authors observed a strong stability globally and regionally, due to the low probability for ports to shift across traffic size groups over time (see also Chapter 5).

The third approach is more qualitative. Scholars discussed the impact of European integration on port concentration as a whole (Gilb, 1992), within UK, and in relation to its Benelux hub (Hilling, 1989; Wilmsmeier and Monios, 2013). Overman and Winters (2005) offered a *New Economic Geography* approach to UK port concentration dynamics, but without mentioning the port system literature. When it comes to governance, there is a consensus that countries with regulated competition and centralized administration have a more concentrated port system (Miyajima and Kwak, 1989; Le and Ieda, 2010; Wang and Ducruet, 2012), while those experiencing liberalization, devolution, integration (merger), and strategic planning exhibit de-concentration (Chaudhury and De, 1999; Wilmsmeier et al., 2014; Nguyen et al., 2018; Feng et al., 2020, 2021). Critiques to port system evolutionary models were proposed in light of actors’ strategies notably in Asia (Slack and Wang, 2002), where the “challenge of peripheral ports” was better explained by governance issues and operational strategies of global terminal operators than by diseconomies of scale in large load centers. In Europe, Frémont and Soppé (2007) demonstrated that the Le Havre – Hamburg range exhibited a stable container port throughput concentration since the 1970s, but a growing shipping line concentration at dedicated hubs, in a context of alliance formation and horizontal integration.

With very few exceptions, the listed analyses were conducted in a context of uninterrupted port growth. It is only recently that scholars analyzed the effects of shocks and crises on port systems (see chapter 14 on the Covid-19 and chapter 15 on the global financial crisis). One early exception is Walker (1989), discussing the impacts of the economic recession on Gulf States ports in the 1980s. The North Korean crisis provoked a drastic reduction of domestic port traffic, which shifted westward and concentrated near Pyongyang (Ducruet, 2008). Looking at exogenous shocks on Kobe, New York, and New Orleans, Rousset and Ducruet (2020) found that traffic rerouting occurred at the periphery of respective regional port systems. Cariou and Notteboom (2022) studied the influence of the Covid-19 on import cargo routing by Walmart and Nike through U.S. ports, also analyzing overall concentration dynamics in the U.S. container port system.

[Insert Table 1.2 about here]

The emergence of new concepts

Taking some distance from the relative linearity of spatial models, economic geographers proposed to analyze port systems in the light of wider concepts and theories. For instance, Notteboom (2009) used the concepts of complementarity and substitutability to analyze the calling patterns of shipping lines among adjacent ports. This work particularly emphasized that large load centers increasingly act as substitutes while smaller ports are more and more complements of the latter. Hall and Jacobs (2010) investigated the various dimensions of proximity between seaports and among port users, from a cognitive and organizational point of view.

Asking "*how do seaports evolve in relation to each other?*", Jacobs and Notteboom (2011) claimed that previous studies on ports "*lack theoretical foundations*". These authors proposed an evolutionary framework to study regional port competition. They particularly developed the concepts of windows of opportunity and the associated 'critical junctures' to analyze the respective roles of the institutional context and of strategic agency in the changing roles and status of ports in the Rhine-Scheldt delta.

Another concept, regional resilience, was used in the analysis of the Chinese port system between 220BC and 2010AD (Wang and Ducruet, 2013). It helped to demonstrate a certain stability in the spatial distribution of main gateways, despite numerous periods of closure and openness. Another example is Monios and Wilmsmeier (2016) in their analysis of port governance and port traffic distribution through the concepts of path-dependency and contingency (see also Wilmsmeier et al., 2014). They particularly showed how port reform (devolution) in Latin America depends on initial institutional settings and what is the outcoming balance of power with the private sector. Path dependence was also used by Castillo and Valdaliso (2017) for the analysis of economic, technological and institutional factors shaping the evolution of the Spanish port system between 1880 and 2014.

The concept of regional integration was explored by Mohamed-Chérif and Ducruet (2016) in the case of the Maghreb based on inter-port container flows, referring to the work of Lemarchand and Joly (2009) on "*regional integration and maritime range*". The latter authors used statistical modelling techniques to measure the level of integration of a port system. They demonstrated that well-integrated port systems should have a negative, significant correlation between the average traffic size of ports and the standard deviation of their yearly growth rates (North America, North Europe). Low integration occurred at port systems welcoming new ports or transshipment hubs (Mediterranean, Asia). In North Africa however, the multiplication of cross-border maritime container linkages was better explained by hub development (Tangier Med) than regional integration.

New types of spatial patterns have been identified, such as multi-port gateway regions (Notteboom, 2010; Feng and Notteboom, 2013; Liu et al., 2013; Pan et al., 2014), bifractal structure (Zhang et al., 2022), multicore port development (Huang et al., 2021), spatial spillovers (Liu and Ping, 2020), and polycentricity (Wang et al., 2017), sometimes considered as new phases extending port system evolutionary models. Explicit reference has been made to peripherality in a number of publications, either as a weakness or counterforce to concentration (Feng and Notteboom, 2013; Feng, 2013; Wilmsmeier and Monios, 2013; Fraser et al., 2016; Wiradanti et al., 2018, 2020).

Maritime connectivity

Most studies of port systems are based on spatial proximity between ports (see Notteboom et al., 2009). Echoing the study by Notteboom et al. (2013) on port research, **Figure 1.3** classifies port system articles according to their geographic reach. It confirms the strong dominance of national-level analyses, except in the 1990s and 2000s. Subnational studies emerged only in the 1990s. There is a clear tendency for larger scales to gain popularity, since the 1980s. This spatial expansion of the scope of analysis may imply changes in the definition and functioning of port systems. It goes along with the fact that a maritime network can be a port system, as the ocean space is relatively borderless: "*every port node can theoretically be linked to every other port node*" (Bird, 1984).

[Insert Figure 1.3 about here]

Very few works studied maritime networks after the work of Robinson (1968). Among them, Marti and Krausse (1983) searched for evidence of load center development in the pattern of transatlantic container flows. Two unpublished PhD dissertations used graph theory to analyze network rationalization (Helmick, 1994) and connectivity (Joly, 1999), respectively. It is only in the late 2000s and early 2010s that increased computational power and shipping data availability made possible the analysis of large maritime networks (see Chapter 15 for an extensive review). For instance, Ducruet et al. (2010) demonstrated that Chinese ports were the largest by traffic volume and the fastest by traffic growth rates, but remained minor nodes in terms of centrality, polarized by Busan and Hong Kong hubs.

The most important contribution of network analysis to port system research has been to identify tightly connected clusters of ports within maritime networks (see a review by Ducruet and Notteboom, 2022). This is because it confers a functional character to the obtained group as opposed to a purely administrative or geographic definition. Depending on the clustering algorithm employed, the nature of the obtained groups and thus of the research question may vary extensively. Single or multiple linkage analysis, focusing on the largest flow(s) of each port node (Nystuen and Dacey, 1961), reveals subsystems or "nodal regions", each polarized by a dominant node in the form of hub-and-spokes structures (Wang and Wang, 2011; Cullinane and Wang, 2012; Ducruet, 2013; Wang and Cullinane, 2014). This structure may be more or less complex (monocentric, polycentric) and its geographic coverage can extend from a given port range to several continents, depending on spatial frictions or "barrier effects" (e.g., distance, borders, coastal morphology). Another method has been to isolate horizontal linkages between nodes of similar connectivity level (topological decomposition). Ducruet and Zaidi (2012) showed that small ports were usually clustered based on geographic proximity, except between Europe and its former African and Latin American colonies. This was considered as a marker of language proximity, trade preferences, and/or historical legacy (e.g., ports of Portugal/Brazil/Angola, Spain/Latin America, and France/North Africa/Caribbean). At the top of the port hierarchy, a cluster of major hub ports formed what is called a "rich-club" in network science. Other methods of graph partitioning and cluster identification were also proposed, including modularity, stochastic blockmodeling, bisecting k-means, and the Louvain algorithm, among many other.

Port system research reaching out to hinterlands

Next to developing a seaward focus through advances in the analysis of nodal-based maritime connectivity and shipping networks, research on port systems has also captured dynamics in hinterland networks. The early models on port system development as presented in the seminal works of Taaffe et al. (1963), Rimmer (1967a, 1967b) and Hayuth (1981) already explicitly considered the role of hinterland corridor infrastructure and connectivity, and the emergence of shared or overlapping hinterlands as important factors shaping concentration dynamics and inter-port competition in seaport systems. Hinterland connections have been recognized as critical to port competitiveness and development in most port systems around the world, requiring coordination between multiple actors often with conflicting mandates (Merk and Notteboom, 2015). In the past 15 years, the conceptualization and empirical analysis of spatial and functional aspects of port-hinterland relations has seen strong growth, particularly in two research domains.

First, there has been a great interest in modelling inter-port competition in port systems by considering the hinterland dimension. The cargo routing choices of shippers and shipping lines depend on a lot of factors such as costs (port, inland transport, sea voyage, feeder/shortsea), time (at sea, in port and to the hinterland), efficiency, inland connectivity of ports of call, frequency, reliability, infrastructure and equipment availability, cargo balance (import/export) and ease of business. Quite a few port choice models have been developed and tested explicitly incorporating hinterland aspects. For example, Biermann and Wedemeier (2016) determined the contestable economic potential of the hinterland of Hamburg and of its possible emerging competitors using simple travel time matrices for different transport modes. The world container model in Tavasszy et al. (2011) models the movement of containers on a global scale. Veldman and Buckmann (2003) and Veldman et al. (2005) applied a container port competition model based on logit analysis to the Le Havre-Hamburg range ports. Also, Zondag et al. (2010) built a container port competition model based on generalized cost for North West Europe. More recently, Mueller et al. (2020) developed a model which includes 31 European mainland container ports, 231 NUTS-2 regions in Europe, and three hinterland transport modes (road, rail and barge) as well as deep-sea and feeder shipping, to analyze port choice. Other examples of spatial-economic analyses of port system-hinterland relations can be found in Guerrero et al. (2021) for the French hinterland; Garcia-Alonso et al. (2016) and Moura et al. (2017) for the Spanish hinterland; Yang et al. (2016) for Shanghai's inland reach; and Wan et al. (2020) on the hinterlands of Chinese major container ports. All these models show that the outcomes are very sensitive to changes in input variables, such as costs, time variables or frequency/reliability.

Second, the discussion on the role of hinterlands in port systems' spatial development saw a new impetus with the introduction of the port regionalization concept by Notteboom and Rodrigue (2005), implying a gradual process where efficiency is derived from higher levels of integration with inland freight distribution systems. Market forces and political influences gradually shape "regional load center networks" with varying degrees of formal linkages between seaports and inland nodes of these networks. The port regionalization thesis sparked a wave of research on inland port/terminals, dry ports, and dry port systems. In broad terms, an inland/dry port can be defined as "an inland facility with or without an intermodal terminal and logistics companies, which is directly connected to seaport(s) with high capacity transport mean(s) either via rail, road or inland waterways, where customers can leave/pick up their standardized units as if directly to a seaport" (Witte et al., 2019 based on Roso et al., 2009 and Wiegmans et al., 2015). The development of intermodal transport corridors connecting seaports to inland/dry ports supported the development of large logistics zones and logistics polarization in the hinterland, while making port hinterlands becoming more discontinuous in nature, in some cases even leading to the establishment of 'islands' i.e. a discontinuous hinterland served by the port but located in the continuous hinterland of another port (Notteboom and Rodrigue, 2005). Witte et al. (2019) identify three phases in the evolution of inland port research and point to a shift in attention to governance and management of inland ports, as well as their spatial and economic impacts to surrounding regions. Some level of conceptualization has taken place with respect to the directional development of inland ports within their specific local, regional and (inter)national contexts. For example, based on the type of vertical control of the development process, Wilmsmeier et al. (2011) distinguished between inside-out development, whereby inland intermodal terminals seek greater integration with their seaports (often driven by public body intervention) and outside-in development whereby inland terminals are used by seaport actors to expand their hinterland. This conceptualization initially applied to Scotland, Sweden and the USA, has been extended, refined and applied in later works, e.g. the outside-in port hinterland integration in Veracruz as analyzed in Wilmsmeier et al. (2015). Witte et al. (2019) rightly observe that most work has followed an outside-in approach. Empirical work has mostly relied on country-based or individual terminal case studies, with only few exceptions such as the global dry port dataset in Nguyen and Notteboom (2019) used to examine the relations between dry port characteristics and regional port-hinterland settings. Several scholars have also embarked on analyzing the spatial development of inland port systems, particularly focusing on major inland waterways such as the Rhine and Yangtze. For example, Veenstra and Notteboom (2011) analyze the structure and development of the Yangtze River port system using statistical measures that have not been used much by transport geographers in ports, and adapt port system development models to river ports. Notteboom et al. (2020) present a comprehensive comparative empirical analysis focusing on the container shipping networks in the Yangtze and the Rhine and show a large diversity in how inland port systems and related gateway seaports are dealing with cargo flows and supply chains. Yang et al. (2021) added an additional layer to the study of inland port systems by examining entry strategies of actors in inland container terminals on the Rhine and Yangtze in terms of their spatial, temporal and institutional characteristics.

Co-operation and integration in port systems: an emerging research field?

There is a multiplication of port integration schemes and mergers at port system level. Recent examples include the 2022 merger between Antwerp and Bruges in Belgium to form the port of Antwerp-Bruges, the creation of HAROPA (Le Havre, Rouen and Paris) in France in 2021, cross-border port mergers such as Copenhagen-Malmo (Denmark/Sweden) and North Sea Port (see Chapter 9 for an in-depth case study), the creation of port system authorities in Italy or the formation of provincial port groups in China. While port co-operation is a hot topic in public and business circles, bibliometric studies on port-related academic research reveal that port co-operation/ integration is an emerging theme, but that the number of published peer reviewed papers is still quite limited in the maritime economic literature (see the content analysis in Pallis et al., 2011 and Woo et al., 2011) and port geography literature (Ng et al., 2014). Still, there is a growing scholarly interest in analyzing the spatial implications of port system co-operation and integration on the triptych foreland-port-hinterland. The edited book on ‘Ports in proximity’ (Notteboom et al., 2009) as well as several volumes on port governance reform and devolution (Brooks and Cullinane, 2006; Brooks et al., 2017) provide a wealth of in-depth case studies on the changing spatial and institutional context within (often national) port systems. More recently, port authority integration and mergers have received more explicit interest as exemplified in a special journal volume by Notteboom et al. (2018). Ducruet et al. (2023) reviewed port cooperation among European ports in the realm of environment and sustainability. The analysis showed that such networks mainly concerned southern ports (see **Table 1.3**), with Valencia as a recurrent leader, while individual projects are more concentrated in northwestern ports. The listed projects are often financed by the European Commission to organize worlshops or to test prototypes of new technologies. Overall, existing publications are mostly case-based descriptive studies. There is room for a more methodological approach in the study of port integration and its spatial implications on port systems.

[Insert Table 1.3 about here]

Port governance integration in China through the formation of port groups at provincial level has gained most interest in recent scholarly work (see e.g., Wang et al., 2015; Notteboom et al., 2017; Yang et al., 2019). The observed port integration in China has led Zhang et al. (2021) to investigate the evolution of the Chinese port system by treating eleven coastal provinces as the units of analysis. Li et al. (2022) investigated the evolution of the integrated port system in the Pearl River Delta (Guangdong-Hong Kong-Macao Greater Bay Area) by applying the evolutionary model of Notteboom and Rodrigue (2005). As the Pearl River Delta is the only major port system in China that has not been subjected to port integration at provincial level, the authors call for a more system-wide coordination and collaboration among ports, aiming to avoid overcapacity (see Chapter 11 by Yang et al.).

The collaboration network of port system scholars

A total of 390 authors base the corpus of port system studies. The analysis of their collaborations is another way to estimate the cohesiveness of the field. Along with the number of publications, the number of authors has increased tremendously over the study period (**Figure 1.4**). What is more relevant to the analysis of collaborations is the parallel increase of the average number of authors by article, from 1.5-2 in the early 2000s to 3-4 in the last years. The extent to which such collaborations form an interconnected network is verified in **Figure 1.5**. We observe that the majority of collaborations are the product of isolated groups of scholars, on the basis of one single article.

In the center of the graph, however, five larger components emerge. Four of them are marked by a strong geographic and/or cultural proximity among scholars, centered on Yeo (South Korea and Vietnam), Ferrari and Parola (Italy), Laxe and Castillo-Manzano (Spain), and Grifoll (Spain and China). The largest component is the "core" of the system by the number of authors and publications. Notteboom appears as the polarizing "hub" connected to most of the different parts of the system directly or indirectly, regardless of a specific geographic logic. Secondary hubs constitute the rest of the backbone, each of them being in an intermediary position between Notteboom and a subset of authors, often based on specific proximities: Ducruet and Europe/Asia, Ng and Europe/Asia, Rodrigue and Slack for Europe/North America, and Wilmsmeier-Monios with a European/Latin American coverage. Four authors play a strategic role at the edge of the network, connecting intermediate hubs with Asia, of which mostly China: Wang C., Wang J.J., Wang L., and Lau, together with Yang and Xu H. to some extent.

It is also important to note that hub authors have more publications than other authors. However, the bridge role of certain authors is not reflected in their publication output. Ng is the third largest author by betweenness centrality after Notteboom and Ducruet, which is the amount of influence a node has over the flow of information in a graph. He is followed by Wang C. and Rodrigue. Without these five hub authors, the network would be nearly disconnected and reduced to small groups, as in the rest of the network.

[Insert Figure 1.4 about here]

[Insert Figure 1.5 about here]

Conclusion

The review proposed in this chapter allows us to conclude that port system research is a buoyant field of analysis. Publications about port systems in peer-reviewed international journals are on the rise. Evolutionary models of the 1960s and 1980s, notwithstanding adjustments, updates, and critiques, continue to be used and diffused today. In parallel, port system research is constantly evolving, by exploring new concepts and methodologies, and strengthening its ties with the wider academic sphere.

Yet, several questions must be asked when taking some distance from this analysis. Given that constructing a corpus is necessarily pragmatic, one may wonder whether the selected articles truly represent port system research. One first reason is that any analysis of port traffic distribution or maritime / hinterland connectivity could potentially belong to the corpus, without necessarily mentioning port systems. The works of De and Park (2003, 2004) and Ding and Teo (2010) on world container throughput concentration are typical examples of the kind. Conversely, numerous works use the concept of port system without referring to any model, in the ordinary sense of the term. The relational perspective is not present in many of the cited works. As such, the boundary between port system and non-port system research is relatively fuzzy.

Another reason is that entire strands of port research were left aside from our analysis despite their relevance and closeness with the topic. Port choice, port selection, shipping network design, and cargo routing dynamics imply that several ports are in competition and thus can be considered as a system. The same applies to port groups within a certain area, like port or maritime regions, ranges, façades, seaboards, basins, and seas, as geographic proximity is in itself a relational factor (see Rodrigue, 2022). Since the majority of port system studies are done at the national level, any analysis of port development in a given country could be considered as a port system study. To avoid the risk of overestimating the importance of port system research however, we restricted the corpus to explicit references to a port system and to models.

As a synthesis, we propose in **Figure 1.6** a general framework to study the various aspects of port systems. This multilevel perspective, with reference to Robinson (1976), implies that certain structures and dynamics at one level can have an influence on other levels. As a spatial model, it does not include elements of policy and governance, trade and economic wealth. Still, it assembles dispersed conceptions of port systems, between land and sea, local and global, hierarchy and specialization, morphology and urbanization. Multilevel empirical applications remain scarce, however, in port studies. The analysis of port choice and competition may include the various elements of the port triptych, but empirical applications usually include a limited number of ports (see Zondag et al., 2010). An analysis of ship turnaround time at about 2300 container ports showed that city size, voyage delays at sea, maximum ship size, and upstream location increase it, while degree centrality, national GDP per capita, the number of vessel calls, and island location have the opposite effect (Ducruet and Itoh, 2022).

[Insert Figure 1.6 about here]

Further research on port systems may follow several pathways. While ports have been seen as complex adaptative systems already (Vonck and Notteboom, 2016), the complex systems framework has been well applied to cities but not to ports. This would allow, for instance, the analysis of coevolution, which has been little explored in a port context (Gerritts, 2011). Simulation models, despite earlier attempts (Kuby et al., 1991; Parola and Sciomachen, 2005; Tavasszy et al., 2011), remain rarely used, and most quantitative analyses are fairly descriptive. If well calibrated, such models have a great potential to forecast past and future changes in traffic distribution, network formation, and hinterland coverage, with the possibility to investigate the impact of changes in one port on other ports (e.g., policies, investments, strategies, etc.). Applications to cities and other transport systems have been proposed already, using generative network models, gravity models, and complex networks among other methods. Very recently, simulation experiments were proposed in the realm of maritime networks to understand their evolutionary processes (Kosowska-Stamirowska, 2020; Kanrak and Nguyen, 2021). Long-term analyses of maritime networks and port systems are becoming more frequent, thanks to the digitization of historical shipping records (see Ducruet, 2017; Olukoju and Castillo, 2020), but more research is needed to check whether similarities emerge among dispersed case studies.

Since ports are more than cargo transshipment nodes but elements in value-driven supply chains (Robinson, 2015) and port cities in production networks (Jacobs et al., 2010), "*The ultimate goal is to be able to analyze the network of networks – sea-land, air and telecommunications – in an all-encompassing study of logistics systems to address the vulnerability of gateways serving multimodal corridors*" (Rimmer, 2015). This would imply that the concept of port system should be extended to a multilayered system where ports are only one element. Research in such ways is already active, looking at air-sea and sea-land connectivity for instance (see a recent review in Ducruet and Guerrero, 2022). This perspective supports the idea that port systems are more than ports, just like "ports are more than piers" (Notteboom, 2006).

References

Berry B.J.L. (1964) Cities as systems within systems of cities. *Papers in Regional Science*, 13(1): 146-163.

Bertalanffy L. von (1950) An outline of general system theory. *British Journal for the Philosophy of Science*, 1: 114-129.

Biermann F., Wedemeier J. (2016) Hamburg's port position: Hinterland competition in Central Europe from TEN-T corridor ports. *HWWI Research Paper*, no. 175.

Bird J.H. (1963) *The Major Seaports of the United Kingdom*. London: Hutchinson.

Bird J.H. (1983) Gateways: slow recognition but irresistible rise. *Tijdschrift voor Economische en Sociale Geografie*, 74(3): 196-202.

Bird J.H. (1984) Seaport development: Some questions of scale. In: Hoyle B.S., Hilling D. (Eds), *Seaport Systems and Spatial Change*, Chichester: Wiley, pp. 21–41.

Brooks M.R., Cullinane K.P.B. (2006) *Devolution, Port Governance and Port Performance*. Elsevier.

Brooks M.R., Cullinane K.P.B., Pallis A.A. (2017) Revisiting port governance and port reform: A multi-country examination. *Research in Transportation Business and Management*, 100(22): 1-10.

Chen L., Xu X., Zhang P., Zhang X. (2018) Analysis on port and maritime transport system researches. *Journal of Advanced Transportation*, https://doi.org/10.1155/2018/6471625

Ding D., Teo C.P. (2010) World container port throughput follows lognormal distribution. *Maritime Policy and Management*, 37(4): 401-426.

Ducruet C. (2005) Structures et dynamiques spatiales des villes portuaires: du local au Mondial. *Mappemonde*, 77(1): https://hal.archives-ouvertes.fr/halshs-00459475/

Ducruet C. (2017) *Advances in Shipping Data Analysis and Modeling. Tracking and Mapping Maritime Flows in the Age of Big Data*. London and New York, Routledge.

Ducruet C. (2020) The geography of maritime networks: a critical review. *Journal of Transport Geography*, 88: 102824.

Ducruet C., Guerrero D. (2022) Inland cities, maritime gateways, and international trade. *Journal of Transport Geography*, 104: 103433.

Ducruet C., Itoh H. (2022) Spatial network analysis of container port operations: The case of ship turnaround times. *Networks and Spatial Economics*, https://doi.org/10.1007/s11067-022-09570-z

Ducruet C., Notteboom T.E., de Langen P.W. (2009) Revisiting inter-port relationships under the New Economic Geography research framework. In: Notteboom T.E., Ducruet C., de Langen P.W. (Eds.), *Ports in Proximity: Competition and Coordination among Adjacent Seaports*, Ashgate, pp. 11-27.

Ducruet C., Panahi R., Ng A.K.Y., Jiang C., Afenyo M. (2019) Between geography and transport: A scientometric analysis of port studies in Journal of Transport Geography. *Journal of Transport Geography*, 81: 102527.

Ducruet C., Lo Prete M., Graef V., Wabnitz K., Ben Hakoun E. (2023) Environment and health in European seaport cities. World Health Organisation Office for Europe, Bonn (forthcoming).

Frémont A., Soppé M. (2007) Northern European range: shipping line concentration and port hierarchy. In: Wang J.J., Olivier D., Notteboom T.E., Slack B. (Eds.) *Ports, Cities, and Global Supply Chains*, Ashgate, Aldershot, pp. 105-120.

Garcia-Alonso L., Martinez-Pardo A., Vallejo-Pinto J.A. (2016) Analysis of the spatial development of the hinterland of ports: a case study. *International Journal of Shipping and Transport Logistics*, 8(2): 111-128.

Gerritts L. (2011) A coevolutionary revision of decision making processes: an analysis of port extensions in Germany, Belgium and the Netherlands. *Public Administration Quarterly*, 35(3): 309-341.

Guerrero D., Montes C.P. (2021) Hinterland. In: *The International Encyclopedia of Geography: People, the Earth, Environment, and Technology*, Wiley.

Helmick J.S. (1994) *Concentration and Connectivity in the North Atlantic Liner Port Network, 1970-1990*. Unpublished PhD Dissertation, Miami: University of Miami.

Hoyle B., Hilling D. (1984) *Seaport Systems and Spatial Change. Technology, Industry, and Development Strategies*. Wiley.

Huo W., Zhang W., Chen P.S.L. (2018) Recent development of Chinese port cooperation strategies. *Research in Transportation Business and Management*, 26: 67-75.

Jacobs W., Ducruet C., de Langen P.W. (2010) Integrating world cities into production networks: the case of port cities. *Global Networks*, 10(1): 92-113.

Joly O. (1999) *La Structuration des Réseaux de Circulation Maritime*. Unpublished PhD dissertation in Territorial Planning, Le Havre University, CIRTAI.

Kanrak M., Nguyen H.O. (2021) Structure, characteristics and connectivity analysis of the Asian-Australasian cruise shipping network. *Maritime Policy and Management*, https://doi.org/10.1080/03088839.2021.1914876

Kosowska-Stamirowska S. (2020) Network effects govern the evolution of maritime trade. *Proceedings of the National Academy of Sciences*, 117(23): 12719-12728.

Lau Y.Y., Ducruet C., Ng A.K.Y., Fu X. (2017) Across the waves: a bibliometric analysis of container shipping research since the 1960s. *Maritime Policy and Management*, 44(6): 667-684.

Lemarchand A., Joly O. (2009) Regional integration and maritime range. In: Notteboom T.E., Ducruet C., de Langen P.W. (Eds.), *Ports in Proximity: Competition and Coordination among Adjacent Seaports*, Ashgate, pp. 87-99.

Ma Q., Jia P., She X., Haralambides H., Kuang H. (2021) Port integration and regional economic development: Lessons from China. *Transport Policy*, 110: 430-439.

Merk O., Notteboom T.E. (2015). Port hinterland connectivity. Discussion paper no. 2015-13, International Transport Forum, OECD: Paris, May 2015.

Moura T.G.Z., Garcia-Alonso L., Salas-Olmedo M.H. (2017) Delimiting the scope of the hinterland of ports: proposal and case study. *Journal of Transport Geography*, 65: 35-43.

Mueller M. A., Wiegmans B., Van Duin J.H.R. (2020) The geography of container port choice: modelling the impact of hinterland changes on port choice. *Maritime Economics & Logistics*, 22(1): 26-52.

Munim Z.H., Saeed N. (2019) Seaport competitiveness research: the past, present and future. *International Journal of Shipping and Transport Logistics*, 11(6): 533-557.

Ng A.K.Y., Ducruet C. (2014) The changing tides of port geography (1950-2012). *Progress in Human Geography*, 38(6): 785-823.

Ng A.K.Y., Ducruet C., Jacobs W., Monios J., Notteboom T.E., Rodrigue J.P., Slack B., Tam K.C., Wilmsmeier G. (2014) Port geography at the crossroads with human geography: between flows and spaces. *Journal of Transport Geography*, 41: 84-96.

Notteboom T.E. (2006) *Ports are More Than Piers: Liber Amicorum Presented to Prof. Dr. Willy Winkelmans*. Antwerpen: De Lloyd.

Notteboom T.E., Ducruet C., de Langen P.W. (2009) *Ports in Proximity: Competition and Coordination among Adjacent Seaports*, Ashgate.

Notteboom T.E., Knatz G., Parola F. (2018) Port co-operation: types, drivers and impediments. *Research in Transportation Business and Management*, 26: 1-4.

Notteboom T.E., Pallis A.A., de Langen P.W., Papachristou A.A. (2013) Advances in port studies: The contribution of 40 years Maritime Policy & Management. *Maritime Policy and Management*, 40(7): 636-653.

Notteboom T.E., Yang Z. (2017) Port governance in China since 2004: Institutional layering and the growing impact of broader policies. *Research in Transportation Business and Management*, 22: 184-200.

Notteboom T.E., Yang D., Xu H. (2020) Container barge network development in inland rivers: A comparison between the Yangtze River and the Rhine River. *Transportation Research Part A*, 132: 587-605.

Nystuen J.D., Dacey M.F. (1961) A graph theory interpretation of nodal regions. *Papers in Regional Science*, 7(1): 29-42.

Olukoju A., Castillo D.H. (2020) *African Seaports and Maritime Economics in Historical Perspective*. Palgrave Studies in Maritime Economics.

Overman H.G., Winters L.A. (2005) The port geography of UK international trade. *Environment and Planning A*, 37(10): 1751-1768.

Pallis A.A., Vitsounis T.K., de Langen P.W., Notteboom T.E. (2011) Port economics, policy and management: Content classification and survey. *Transport Reviews*, 31(4): 445-471.

Pounds N.J.G. (1947) Port and outport in North-West Europe. *The Geographical Journal*, 109(4-6): 216-228.

Pumain D. (2004) Système. *Hypergeo*, 29 April, https://hypergeo.eu/systeme/

Rimmer P.J. (2015) Foreword. In: Ducruet C. (Ed.), *Maritime Networks. Spatial Structures and Time Dynamics*, London and New York: Routledge, pp. xxi-xxii.

Robinson R. (1968) *Spatial Structuring of Port-Linked Flows; The Port of Vancouver, Canada, 1965*. Unpublished PhD dissertation in Geography, University of British Columbia.

Robinson R. (1976) Modelling the port as an operational system: A perspective for research. *Economic Geography*, 52(1): 71-86.

Robinson R. (2015) Afterword. In: Ducruet C. (Ed.), *Maritime Networks. Spatial Structures and Time Dynamics*, London and New York: Routledge, pp. 374-377.

Rodrigue J.P. (2022) The geography of maritime ranges: interfacing global maritime shipping networks with hinterlands. *Geojournal*, 87: 1231-1244.

Roso V., Woxenius J., Lumsden K. (2009) The dry port concept: connecting container seaports with the hinterland. *Journal of Transport Geography*, 17(5): 338-345.

Sanders L. (2005) Spatial system. *Hypergeo*, 12 January, https://hypergeo.eu/spatial-system/?lang=en

Veldman S.J., Bückmann E.H. (2003) A model on container port competition: an application for the West European container hub-ports. *Maritime Economics & Logistics*, 5(1): 3-22.

Veldman S.J., Bückmann E.H., Saitua R.N. (2005) River depth and container port market shares: the impact of deepening the Scheldt river on the west European container hub-port market shares. *Maritime Economics & Logistics*, 7(4): 336-355.

Vigarié A. (1964) *Les Grands Ports de Commerce de la Seine au Rhin: Leur Evolution Devant l'Industrialisation des Arrière-Pays*. Paris: S.A.B.R.I.

Vigarié A. (1979) *Ports de Commerce et Vie Littorale*. Paris: Hachette.

Wan S., Luan W., Ma Y., Haralambides H. (2020) On determining the hinterlands of China's foreign trade container ports. *Journal of Transport Geography*, 85: 102725.

Wang C., Ducruet C., Wang W. (2015) Port integration in China: Temporal pathways, spatial patterns and dynamics. *Chinese Geographical Science*, 25(5): 612-628.

Wang S.B., Peng X.H. (2021) Knowledge mapping of port logistics in the recent 20 Years: a bibliometric analysis via CiteSpace. *Maritime Policy and Management*, https://doi.org/10.1080/03088839.2021.1990429

Wilmsmeier, G., Monios, J., Lambert, B. (2011) The directional development of intermodal freight corridors in relation to inland terminals. *Journal of Transport Geography*, 19: 1379–1386.

Woo S.H., Pettit S.J., Kwak D.W., Beresford A.K.C. (2011) Seaport research: A structured literature review on methodological issues since the 1980s. *Transportation Research Part A*, 45: 667-685.

Xu X., Wang H., WU Y., Yi W. (2021) Bibliometric analysis on port and shipping researches in scope of management science. *Asia-Pacific Journal of Operational Research*, 38(3): 2140027.

Yang Z., Guo L., Lian F. (2019) Port integration in a region with multiport gateways in the context of industrial transformation and upgrading of the port. *Transportation Research Part E*, 122: 231-246.

Yang J., Luo M., Ji A. (2016) Analyzing the spatial–temporal evolution of a gateway's hinterland: A case study of Shanghai, China. *Transportation Research Part E*, 95: 355-367.

Yang D., Notteboom T.E., Zhou X. (2021) Spatial, temporal and institutional characteristics of entry strategies in inland container terminals: a comparison between Yangtze River and Rhine River. *Journal of Transport Geography*, 90: 102928.

Zondag B., Bucci P., Gützkow P., de Jong G. (2010) Port competition modeling including maritime, port, and hinterland characteristics. *Maritime Policy and Management*, 37(3): 179-194.

Appendix 1.1: Corpus of port system articles, 1963-2022

1. Acciaro M., Bardi A., Cusano M.I. (2017) Contested port hinterlands: An empirical survey on Adriatic seaports. *Case Studies on Transport Policy*, 5(2): 342–350.
2. Airriess C. (1995) Port-centered transport development in colonial North Sumatra. *Indonesia*, 59: 65–91.
3. Bacon J.R., Halbrendt C.K., Gempesaw C.M. (1990) Food trade flows of the Delaware River port system. *Journal of Food Distribution Research*, 21(2): 39–40.
4. Balic K., Žgaljic D., Ukic Boljat H. (2022) The port system in addressing sustainability issues—a systematic review of research. *Journal of Marine Science and Engineering*, 10(8): 1048.
5. Beškovnik B., Twrdy E. (2015) Developing regional approach for transport industry: the role of port system in the Balkans. *Transport*, 30(4): 437–447.
6. Blanco B., Sánchez L., Gutierrez C. (2016) Port system of the Spanish South Peninsular coast side. *Journal of Maritime Research*, 13(1): 15–24.
7. Blanco B., Sánchez L., Pellón M. (2015) Port system of the Spanish Mediterranean coast side. *Journal of Maritime Research*, 12(2): 35–44.
8. Bobrovitch D. (1982) Decentralised planning and competition in a national multi-port system. *Journal of Transport Economics and Policy*, 16(1): 31–42.
9. Bonilla M., Casarús S.R., Medal A. (2004) An efficiency analysis with tolerance of the Spanish port system. *International Journal of Transport Economics*, 31(3): 1000–1022.
10. Broeze F.J.A. (1996) The ports and port system of the Asian Seas: an overview with historical perspective from c1750. *The Great Circle: Journal of the Australian Association for Maritime History*, 18(2): 73–96.
11. Brunt B. (2000) Ireland's seaport system. *Tijdschrift voor Economische en Sociale Geografie*, 91(2): 159–175.
12. Cariou P., Notteboom T.E. (2022) Implications of COVID-19 on the US container port distribution system: import cargo routing by Walmart and Nike. *International Journal of Logistics Research and Applications*, https://doi.org/10.1080/13675567.2022.2088708
13. Castillo D., Valdaliso J.M. (2017) Path dependence and change in the Spanish port system in the long run (1880–2014): An historical perspective. *International Journal of Maritime History*, 29(3): 569–596.
14. Castillo-Manzano J.I., Castro-Nuño M., González-Laxe F. (2009) Low-cost port competitiveness index: Implementation in the Spanish port system. *Marine Policy*, 33(4): 591–598.
15. Castillo-Manzano J.I., Castro-Nuño M., González-Laxe F. (2014) An analysis of the determinants of cruise traffic: An empirical application to the Spanish port system. *Transportation Research Part E*, 66: 115–125.
16. Castillo-Manzano J.I., Castro-Nuño M., González-Laxe F. (2018) Legal reform and the devolution of the Spanish Port System: An econometric assessment. *Utilities Policy*, 50: 73–82.
17. Charlier J. (1988) Structural change in the Belgian port system, 1980–1986. *Maritime Policy and Management*, 15(4): 315–326.
18. Charlier J. (1996) The Benelux seaport system. *Tijdschrift voor Economische en Sociale Geografie*, 87(4): 310–321.
19. Chaudhury B., De P. (1999) Concentration of Indian Port System: 1970-1998. *Foreign Trade Review*, 34(3-4): 33–46.
20. Chlomoudis C., Styliadis T. (2019) Concentration of container flows in the port phase: the case of the US West and East Coast port ranges. *Issues in Business Management and Economics*, 7(1): 1–21.
21. Comtois C. (1999) The integration of China's port system into global container shipping. *GeoJournal*, 48(1): 35–42.
22. Comtois C., Dong J. (2007) Port competition in the Yangtze River delta. *Asia Pacific Viewpoint*, 48(3): 299–311.
23. Cullinane K., Wang Y. (2012) The hierarchical configuration of the container port industry: an application of multiple linkage analysis. *Maritime Policy and Management*, 39(2): 169–187.

24. Danielis R., Gregori T. (2013) An input-output-based methodology to estimate the economic role of a port: The case of the port system of the Friuli Venezia Giulia Region, Italy. *Maritime Economics & Logistics*, 15(2): 222–255.
25. de Langen P.W. (2007) Port competition and selection in contestable hinterlands: the case of Austria. *European Journal of Transport and Infrastructure Research*, 7(1): 1-14.
26. de Oliveira G.F., Schaffar A., Cariou P., Monios J. (2021) Convergence and growth traps in container ports. *Transport Policy*, 110: 170–180.
27. De P., Park R.K. (2003) Container port system concentration. *Transportation Quarterly*, 57(4): 69-82.
28. De P., Park R.K. (2004) International container port system concentration: what does it look like. *Journal of International Logistics and Trade*, 2(1): 95–118.
29. Debrie J. (2012) The West African port system: global insertion and regional particularities. *EchoGéo*, (20): https://doi.org/10.4000/echogeo.13070
30. Deng Z., Li Z.F., Zhou Y.T., Chen X., Liang S.S. (2020) Measurement and spatial spillover effects of port comprehensive strength: Empirical evidence from China. *Transport Policy*, 99: 288–298.
31. Do N.H., Nam K.C., Le Ngoc Q.L. (2011) A consideration for developing a dry port system in Indochina area. *Maritime Policy and Management*, 30(1): 1-9.
32. Ducruet C. (2008) Hub dependence in constrained economies: the case of North Korea. *Maritime Policy and Management*, 35(4): 377–394.
33. Ducruet C. (2013) Network diversity and maritime flows. *Journal of Transport Geography*, 30(): 77–88.
34. Ducruet C. (2017) Multilayer dynamics of complex spatial networks: The case of global maritime flows (1977–2008). *Journal of Transport Geography*, 60(): 47–58.
35. Ducruet C. (2020) Revisiting urban hierarchy and specialization from a maritime perspective. *Maritime Policy and Management*, 47(3): 371-387.
36. Ducruet C. (2022) Port specialization and connectivity in the global maritime network. *Maritime Policy and Management*, 49(1): 1–17.
37. Ducruet C., Cuyala S., El Hosni A. (2018) Maritime networks as systems of cities: The long-term interdependencies between global shipping flows and urban development (1890–2010). *Journal of Transport Geography*, 66: 340–355.
38. Ducruet C., Itoh H. (2022) The spatial determinants of innovation diffusion: Evidence from global shipping networks. *Journal of Transport Geography*, 101: 103358.
39. Ducruet C., Jo J.C. (2008) Coastal cities, port activities and logistic constraints in a socialist developing country: the case of North Korea. *Transport Reviews*, 28(1): 35–59.
40. Ducruet C., Koster H.R.A., van der Beek D.J. (2010) Commodity variety and seaport performance. *Regional Studies*, 44(9): 1221-1240.
41. Ducruet C., Lee S.W. (2006) Frontline soldiers of globalisation: Port–city evolution and regional competition. *GeoJournal*, 67(2): 107–122.
42. Ducruet C., Lee S.W., Ng A.K.Y. (2010) Centrality and vulnerability in liner shipping networks: revisiting the Northeast Asian port hierarchy. *Maritime Policy and Management*, 37(1): 17–36.
43. Ducruet C., Notteboom T.E. (2012) The worldwide maritime network of container shipping: spatial structure and regional dynamics. *Global networks*, 12(3): 395–423.
44. Ducruet C., Notteboom T.E. (2022) Revisiting port system delineation through an analysis of maritime interdependencies among seaports. *GeoJournal*, 87: 1831–1859.
45. Ducruet C., Roussin S., Jo J.C. (2009) Going West? Spatial polarization of the North Korean port system. *Journal of Transport Geography*, 17(5): 357–368.
46. Ducruet C., Wang L. (2018) China's global shipping connectivity: internal and external dynamics in the contemporary era (1890–2016). *Chinese Geographical Science*, 28(2): 202-216.
47. Ducruet C., Zaidi F. (2012) Maritime constellations: a complex network approach to shipping and ports. *Maritime Policy and Management*, 39(2): 151–168.
48. Escobar M.C.M. (2021) Roman ports in the lower Tiber valley: computational approaches to reassess Rome's port system. *Papers of the British School at Rome*, 1–30, doi:10.1017/S0068246221000271

49. Esparza A., Cerbán M.M., Piniella F. (2017) State-owned Spanish port system oversizing: an analysis of maximum operational capacity. *Maritime Policy and Management*, 44(8): 995–1011.
50. Esteve-Pérez J., Gutiérrez-Romero J.E. (2022) Assessment of the dynamics of concentration and competitive positions of the Baltic cruise port system. *European Transport Research Review*, 14(1): 1–13.
51. Fan F., Zhang X., Yang W. (2021) Spatiotemporal evolution of China's ports in the international container transport network under upgraded industrial structure. *Transportation Journal*, 60(1): 43–69.
52. Feng H., Grifoll M., Yang Z. (2020) Visualization of container throughput evolution of the Yangtze River Delta multi-port system: the ternary diagram method. *Transportation Research Part E*, 142: 102039.
53. Feng H., Grifoll M., Zheng P. (2019) From a feeder port to a hub port: The evolution pathways, dynamics and perspectives of Ningbo-Zhoushan port (China). *Transport Policy*, 76: 21–35.
54. Feng H., Grifoll M., Zheng P. (2021) Evolution and container traffic prediction of Yangtze River Delta multi-port system (2001–2017). *International Journal of Shipping and Transport Logistics*, 13(1): 44–57.
55. Feng L. (2013) Regression analysis on the hinterland connection of peripheral ports in the China Bohai Sea regions. *International Journal of Advances in Management Science*, 2(4): 159–162.
56. Feng L., Notteboom T.E. (2013) Peripheral challenge by small and medium sized ports (SMPs) in multi-port gateway regions: the case study of northeast of China. *Polish Maritime Research*, 20: 55-66.
57. Feng X., Jiang L., Zhang Y. (2011) Optimization of capacity of ports within a regional port system. *Transportation Research Record*, 2222(1): 10–16.
58. Feng X., Zhang Y., Li Y. (2013) A location-allocation model for seaport-dry port system optimization. *Discrete Dynamics in Nature and Society*, 2013: https://doi.org/10.1155/2013/309585
59. Ferrari C., Parola F., Benacchio M. (2008) Network economies in liner shipping: the role of home markets. *Maritime Policy and Management*, 35(2): 127–143.
60. Ferrari C., Parola F., Gattorna E. (2011) Measuring the quality of port hinterland accessibility: The Ligurian case. *Transport Policy*, 18(2): 382–391.
61. Franc P., Van der Horst M. (2010) Understanding hinterland service integration by shipping lines and terminal operators: a theoretical and empirical analysis. *Journal of Transport Geography*, 18(4): 557–566.
62. Fraser D.R., Notteboom T.E. (2012) Gateway and hinterland dynamics: the case of the Southern African container port system. *African Journal of Business Management*, 44(6): 10807–10825.
63. Fraser D.R., Notteboom T.E., Ducruet C. (2016) Peripherality in the global container shipping network: the case of the Southern African container port system. *GeoJournal*, 81(1): 139–151.
64. Galvão C.B., Robles L.T., Guerise L.C. (2013) The Brazilian seaport system: A post-1990 institutional and economic review. *Research in Transportation Business and Management*, 8: 17-29.
65. Garcia-Alonso L., Sanchez-Soriano J. (2010) Analysis of the evolution of the inland traffic distribution and provincial hinterland share of the Spanish port system. *Transport Reviews*, 30(3): 275–297.
66. Ghosh B., De P. (2001) Indian ports and globalisation: Grounding economics in geography. *Economic and Political Weekly*, 36(34): 3271–3283.
67. Gilb C.L. (1992) Factors contributing to change in the European port system. *Landscape and Urban Planning*, 22(2-4): 205–217.
68. González A.R., González-Cancelas N., Serrano B.M. (2020) Smart ports: ranking of Spanish port system. *World Scientific News*, 144: 1–12.
69. González-Laxe F., Bermúdez F.M., Palmero F.M. (2016) Sustainability and the Spanish port system. Analysis of the relationship between economic and environmental indicators. *Marine Pollution Bulletin*, 113(1-2): 232–239.
70. Gouvernal E., Debrie J., Slack B. (2005) Dynamics of change in the port system of the western Mediterranean. *Maritime Policy and Management*, 32(2): 107–121.
71. Grifoll M., Karlis T., Ortego M.I. (2018) Characterizing the evolution of the container traffic share in the Mediterranean Sea using hierarchical clustering. *Journal of Marine Science and Engineering*, 6(4): https://doi.org/10.3390/jmse6040121
72. Grushevska K., Notteboom T.E. (2014) An economic and institutional analysis of multi-port gateway regions in the Black Sea Basin. *Journal of International Logistics and Trade*, 12(2): 3–35.

73. Grushevska K., Notteboom T.E. (2016) The development of river-based intermodal transport: the case of Ukraine. *Journal of International Logistics and Trade*, 14(3): 182–199.
74. Guerrero D. (2014) Deep-sea hinterlands: Some empirical evidence of the spatial impact of containerization. *Journal of Transport Geography*, 35: 84–94.
75. Guerrero D., Rodrigue J.P. (2014) The waves of containerization: shifts in global maritime transportation. *Journal of Transport Geography*, 34: 151–164.
76. Guy E., Urli B. (2006) Port selection and multicriteria analysis: An application to the Montreal-New York alternative. *Maritime Economics & Logistics*, 8(2): 169–186.
77. Haezendonck E., Coeck C., Verbeke A. (2000) The competitive position of seaports: introduction of the value added concept. *International Journal of Maritime Economics*, 2(2): 107–118.
78. Haezendonck E., Coeck C., Verbeke A. (2006) Strategic positioning analysis for seaports. *Research in Transportation Economics*, 16: 141–169.
79. Hall P.V. (2004) Mutual specialisation, seaports and the geography of automobile imports. *Tijdschrift voor Economische en Sociale Geografie*, 95(2): 135–146.
80. Hall, Peter V, Jacobs, Wouter, (2010) Shifting proximities: The maritime ports sector in an era of global supply chains. Regional studies, 44(9): 1103–1115.
81. Hayuth Y. (1981) Containerization and the load center concept. *Economic Geography*, 57(2): 160–176.
82. Hayuth Y. (1988) Rationalization and deconcentration of the US container port system. *The Professional Geographer*, 40(3): 279–288.
83. Hayuth Y. (1991) Load centering competition and modal integration. *Coastal Management*, 19(3): 297–311.
84. He D., Sun Z., Gao P. (2019) Spatial–temporal evolution of the port–hinterland relationship: A case study of the Midstream Yangtze River, China. *Growth and Change*, 50(3): 1043–1061.
85. Heilig L., Lalla-Ruiz E., Voß S. (2017) Digital transformation in maritime ports: analysis and a game theoretic framework. *Netnomics*, 18(2): 227–254.
86. Hidalgo-Gallego S., Núñez-Sánchez R., Coto-Millán P. (2022) Port allocative efficiency and port devolution: a study for the Spanish port authorities (1992-2016). *Maritime Policy and Management*, 49(1): 39–61.
87. Hilling D. (1969) The evolution of the major ports of West Africa. *The Geographical Journal*, 135(3): 365–378.
88. Hilling D. (1977) The evolution of a port system - the case of Ghana. *Geography*, 62(2): 97-105.
89. Hilling D. (1989) Technology and the changing port system of England and Wales. *Geography*, 74(2): 117–127.
90. Hoyle B. (1999) Port concentration, inter-port competition and revitalization: the case of Mombasa, Kenya. *Maritime Policy and Management*, 26(2): 161–174.
91. Hoyle B., Charlier J. (1995) Inter-port competition in developing countries: an East African case study. *Journal of Transport Geography*, 3(2): 87–103.
92. Huang D., Grifoll M., Feng H. (2021) Characterizing the evolution of the Yangtze River Delta multi-port system using compositional data techniques. *Maritime Policy and Management*, https://doi.org/10.1080/03088839.2021.1972175
93. Ignaccolo M., Inturri G., Giuffrida N. (2020) Sustainability of freight transport through an integrated approach: the case of the Eastern Sicily port system. *Transportation Research Procedia*, 45: 177–184.
94. Iyer K.C., Nanyam V.P.S.N. (2021) Concentration analysis of container terminals in India. *Maritime Transport Research*, 2: 100037.
95. Jacobs W., Notteboom T.E. (2011) An evolutionary perspective on regional port systems: the role of windows of opportunity in shaping seaport competition. *Environment and Planning A*, 43(7): 1674–1692.
96. Jaja C. (2009) Port development in Nigeria: Trends and patterns. *Journal of Transportation Security*, 2(4): 107–119.
97. Jeevan J., Harun M., Abdullah W.M.W., Othman M.R., Mohd Salleh N.H., Caesar L.D. (2021) The belt and road initiative: a pragmatic constituent for the growth of Malaysian seaport system. *World Review of*

Intermodal Transport Research, 10(3): https://www.inderscienceonline.com/doi/pdf/10.1504/WRITR.2021.117668

98. Jiang C., Fu X., Ge Y.E. (2021) Vertical integration and capacity investment in a two-port system. *Transportmetrica A: Transport Science*, 17(4): 1431–1459.
99. Jiang Z., Pi C., Zhu H. (2022) Temporal and spatial evolution and influencing factors of the port system in Yangtze River Delta Region from the perspective of dual circulation: Comparing port domestic trade throughput with port foreign trade throughput. *Transport Policy*, 118: 79–90.
100. Jin L., Chen J., Sheu J.B. (2022) Impacts of national strategies on gateway ports: An empirical study in the Bohai Rim. *Transport Policy*, 117: 1–11.
101. John A., Yang Z., Riahi R., Wang J. (2016) A risk assessment approach to improve the resilience of a seaport system using Bayesian networks. *Ocean Engineering*, 111: 136-147.
102. Jones J.R, Qu L., Casavant K.L. (1995) A spatial equilibrium port cargo projection model. *Maritime Policy and Management*, 22(1): 63–80.
103. Jung P.H., Thill J.C. (2022) Sea-land interdependence and delimitation of port hinterland-foreland structures in the international transportation system. *Journal of Transport Geography*, 99: 103297.
104. Kim S., Kang D., Dinwoodie J. (2016) Competitiveness in a multipolar port system: striving for regional gateway status in Northeast Asia. *The Asian Journal of Shipping and Logistics*, 32(2): 119–125.
105. Konings R. (2007) Opportunities to improve container barge handling in the port of Rotterdam from a transport network perspective. *Journal of Transport Geography*, 15(6): 443–454.
106. Kozan E. (1994) Analysis of the economic effects of alternative investment decisions for seaport systems. *Transportation Planning and Technology*, 18(3): 239-248.
107. Krivoshchekov P., Pham T.Y., Yeo G.T. (2018) Seaport concentration and competition development in the Arctic region of Russia along the North Sea Route. *Journal of Digital Convergence*, 16(4): 49–54.
108. Kuby M., Ratick S., Osleeb J. (1991) Modeling US coal export planning decisions. *Annals of the Association of American Geographers*, 81(4): 627–649.
109. Kuby M., Reid N. (1992) Technological change and the concentration of the US general cargo port system: 1970–88. *Economic Geography*, 68(3): 272–289.
110. Kurt I., Aymelek M., Boulougouris E. (2021) Operational cost analysis for a container shipping network integrated with offshore container port system: A case study on the West Coast of North America. *Marine Policy*, 126: 104400.
111. Lam J.S.L., Yap W.Y. (2011) Container port competition and complementarity in supply chain systems: Evidence from the Pearl River Delta. *Maritime Economics & Logistics*, 13(2): 102–120.
112. Le Y., Ieda H. (2010) Evolution dynamics of container port systems with a geo-economic concentration index. *Asian Transport Studies*, 1(1): 46–61.
113. Le Y., Ieda H. (2010) Modified Herfindahl–Hirschman index for measuring the concentration degree of container port systems. *Transportation Research Record*, 2166(1): 44–53.
114. Lee J.Y., Rodrigue J.P. (2006) Trade reorientation and its effects on regional port systems: The Korea-China link along the Yellow Sea Rim. *Growth and Change*, 37(4): 597–619.
115. Lee T., Yeo G.T., Thai V.V. (2014) Changing concentration ratios and geographical patterns of bulk ports: the case of the Korean West coast. *The Asian Journal of Shipping and Logistics*, 30(2): 155–173.
116. Le-Griffin H.D., Griffin M.T., (2010) Managing empty container flows through short sea shipping and regional port systems. *International Journal of Shipping and Transport Logistics*, 2(1): 59–75.
117. Li J.B., Oh Y.S. (2010) A research on competition and cooperation between Shanghai port and Ningbo-Zhoushan port. *The Asian Journal of Shipping and Logistics*, 26(1): 67–91.
118. Li K.X., Luo M., Yang J. (2012) Container port systems in China and the USA: a comparative study. *Maritime Policy and Management*, 39(5): 461–478.
119. Li S., Haralambides H., Zeng Q. (2022) Economic forces shaping the evolution of integrated port systems-The case of the container port system of China's Pearl River Delta. *Research in Transportation Economics*, 94: 101183.

120. Li W., You Z., Cai Z., Sui Y. (2022) Club convergence and allometry in Chinese mainland coastal container ports. *Ocean and Coastal Management*, 230: 106376.
121. Liu L., Ping H. (2020) Study of the influencing factors on development of ports in Guangdong, Hong Kong, and Macao from the perspective of spatial economics. *Mathematical Problems in Engineering*, 2020: https://doi.org/10.1155/2020/2343860
122. Liu L., Wang K.Y., Yip T.L. (2013) Development of a container port system in Pearl River Delta: path to multi-gateway ports. *Journal of Transport Geography*, 28: 30–38.
123. Liu S., Nguyen T.H., Yeo G.T. (2018) The evolution of container port group in Bohai Rim of China. *Journal of Digital Convergence*, 16(9): 107–114.
124. Liu S., Yeo G.T. (2020) A study on the concentration and deconcentration development for cruise ports in Mediterranean Sea. *Journal of Digital Convergence*, 18(7): 37–46.
125. López-Bermúdez B., Freire-Seoane M.J., Lesta-Casal E. (2020) Core and comprehensive ports: The new challenge for the development of the Spanish port system. *Transportation Research Interdisciplinary Perspectives*, 8: 100243.
126. Ma Q., Jia P., She X. (2021) Port integration and regional economic development: Lessons from China. *Transport Policy*, 110: 430–439.
127. Marcadon J. (1999) Containerisation in the ports of Northern and Western Europe. *GeoJournal*, 48(1): 15-20.
128. Marti B.E. (1981) Patterns of United States–Canadian maritime container flows. *Maritime Policy and Management*, 8(4): 253–259.
129. Marti B.E. (1985) Chilean ports: commodity specialization and potential for containerization. *The Professional Geographer*, 37(3): 320–328.
130. Marti B.E. (1988) The evolution of Pacific Basin load centres. *Maritime Policy and Management*, 15(1): 57–66.
131. Marti B.E. (1990) Geography and the cruise ship port selection process. *Maritime Policy and Management*, 17(3): 157–164.
132. Marti B.E., Krausse G.H. (1983) Trade route 11: Methods to assess port exchanges of maritime containerized cargo flows. *Ocean Management*, 8(4): 317–333.
133. Marušic E., Šoda J., Krcum M. (2020) The three-parameter classification model of seasonal fluctuations in the Croatian nautical port system. *Sustainability*, 12(12): 5079.
134. Maucec H., Zelenika R., Sever D. (2013) Development rate of maritime container ports: A case of transatlantic ports. *Journal of Maritime Research*, 10(2): 11–20.
135. McCalla R.J. (1999) From St. John's to Miami: Containerisation at eastern seaboard ports. *GeoJournal*, 48(1): 21–28.
136. Medal-Bartual A., Molinos-Senante M., Sala-Garrido R. (2016) Productivity change of the Spanish Port System: impact of the economic crisis. *Maritime Policy and Management*, 43(6): 683–705.
137. Medda F., Carbonaro G. (2007) Growth of container seaborne traffic in the Mediterranean basin: outlook and policy implications for port development. *Transport Reviews*, 27(5): 573–587.
138. Memon A., Milne M.J., Selsky J.W. (2004) Restructuring governance of New Zealand seaports: Geographical impacts of corporatisation. *New Zealand Geographer*, 60(2): 15–27.
139. Michael O.O. (2019) An appraisal of containerization in ports of western and eastern Nigeria. *International Journal for Traffic and Transport Engineering*, 9(2): 188-197.
140. Miyajima M., Kwak K.S. (1989) Economic analysis of interport competition in container cargo: peripheral ports versus Tokyo Bay ports. *Maritime Policy and Management*, 16(1): 47–55.
141. Mohamed-Chérif F., Ducruet C. (2016) Regional integration and maritime connectivity across the Maghreb seaport system. *Journal of Transport Geography*, 51: 280–293.
142. Mohd Salleh N.H., Abd Rasidi N.A.S., Jeevan J. (2020) Lean, agile, resilience and green (LARG) paradigm in supply chain operations: a trial in a seaport system. *Australian Journal of Maritime and Ocean Affairs*, 12(4): 200-216.

143. Mohd Salleh N.H., Selvaduray M., Jeevan J., Ngah A.H., Zailani S. (2021) Adaptation of industrial revolution 4.0 in a seaport system. *Sustainability*, 13(19): 10667.
144. Monios J. (2017) Cascading feeder vessels and the rationalisation of small container ports. *Journal of Transport Geography*, 59: 88–99.
145. Monios J., Wilmsmeier G. (2012) Giving a direction to port regionalisation. *Transportation Research Part A*, 46(10): 1551–1561.
146. Monios J., Wilmsmeier G. (2013) The role of intermodal transport in port regionalisation. *Transport Policy*, 30: 161–172.
147. Monios J., Wilmsmeier G. (2016) Between path dependency and contingency: new challenges for the geography of port system evolution. *Journal of Transport Geography*, 51(2): 247-251.
148. Monios J., Wilmsmeier G., Ng A.K.Y. (2019) Port system evolution–the emergence of second-tier hubs. *Maritime Policy and Management*, 46(1): 61–73.
149. Montes C.P., Seoane M.J.F., Laxe F.G. (2012) General cargo and containership emergent routes: A complex networks description. *Transport Policy*, 24: 126–140.
150. Mulder J., Dekker R. (2014) Methods for strategic liner shipping network design. *European Journal of Operational Research*, 235(2): 367–377.
151. Muravev D., Rakhmangulov A. (2016) Environmental factors' consideration at industrial transportation organization in the «seaport–dry port» system. *Open Engineering*, 6(1): 476-484.
152. Navarro-Chávez C.L., Zamora-Tores A.I. (2014) Economic efficiency of the international port system: An analysis through data envelopment. *International Business Research*, 7(11): 108-116.
153. Nguyen P.N., Woo S.H., Beresford A. (2020) Competition, market concentration, and relative efficiency of major container ports in Southeast Asia. *Journal of Transport Geography*, 83: 102653.
154. Nguyen T.H., Pham T.Y., Yeo G.T. (2018) Deconcentration pattern of port system: Case in Southern Vietnam. *Journal of Digital Convergence*, 16(3): 157–167.
155. Nguyen T.V., Nguyen H.P. (2020) A study on forecasting model of container cargo throughput of Vietnam's seaport. *International Journal of e-Navigation and Maritime Economy*, 14: 75–88.
156. Notteboom T.E. (1997) Concentration and load centre development in the European container port system. *Journal of Transport Geography*, 5(2): 99–115.
157. Notteboom T.E. (2006) Container throughput dynamics in the East Asian container port system. *Journal of International Logistics and Trade*, 4(1): 31–52.
158. Notteboom T.E. (2006) Traffic inequality in seaport systems revisited. *Journal of Transport Geography*, 14(2): 95–108.
159. Notteboom T.E. (2007) Container river services and gateway ports: Similarities between the Yangtze River and the Rhine River. *Asia Pacific Viewpoint*, 48(3): 330–343.
160. Notteboom T.E. (2007) Spatial dynamics in the container load centers of the Le Havre-Hamburg range. *Zeitschrift für Wirtschaftsgeographie*, 51(1): 108–123.
161. Notteboom T.E. (2009) Complementarity and substitutability among adjacent gateway ports. *Environment and Planning A*, 41(3): 743-762.
162. Notteboom T.E. (2010) Concentration and the formation of multi-port gateway regions in the European container port system: an update. *Journal of Transport Geography*, 18(4): 567–583.
163. Notteboom T.E. (2010) From multi-porting to a hub port configuration: the South African container port system in transition. *International Journal of Shipping and Transport Logistics*, 2(2): 224–245.
164. Notteboom T.E. (2011) An application of multi-criteria analysis to the location of a container hub port in South Africa. *Maritime Policy and Management*, 38(1): 51–79.
165. Notteboom T.E., Rodrigue J.P. (2005) Port regionalization: towards a new phase in port development. *Maritime Policy and Management*, 32(3): 297–313.
166. Notteboom T.E., Yang D., Xu H. (2020) Container barge network development in inland rivers: A comparison between the Yangtze River and the Rhine River. *Transportation Research Part A*, 132: 587–605.

167. Ogundana B. (1972) Oscillating seaport location in Nigeria. *Annals of the Association of American Geographers*, 62(1): 110-121.
168. Olivier D., Slack B. (2006) Rethinking the port. *Environment and Planning A*, 38(8): 1409–1427.
169. Padilha F., Ng A.K.Y. (2012) The spatial evolution of dry ports in developing economies: The Brazilian experience. *Maritime Economics & Logistics*, 14(1): 99–121.
170. Paiva T.M., Santos R.F. (2022) The Brazilian port system: a panorama of informational processes for importing and exporting containerized cargo. *Revista Gestão & Tecnologia*, 22(2): 175–200.
171. Pan K., Cao Y., Liang S. (2014) New tendency of Chinese container port system: 1998–2010. *GeoJournal*, 79(3): 373–384.
172. Parola F., Musso E. (2007) Market structures and competitive strategies: the carrier–stevedore arm-wrestling in northern European ports. *Maritime Policy and Management*, 34(3): 259–278.
173. Parola F., Sciomachen A. (2005) Intermodal container flows in a port system network: Analysis of possible growths via simulation models. *International Journal of Production Economics*, 97(1): 75–88.
174. Pedersen P. (2003) Development of freight transport and logistics in Sub-Saharan Africa: Taaffe, Morrill and Gould revisited. *Transport Reviews*, 23(3): 275–297.
175. Pham T.Y., Jeon J.W., Dang V.L. (2016) A longitudinal analysis of concentration developments for container terminals in Northern Vietnam. *The Asian Journal of Shipping and Logistics*, 32(3): 157–164.
176. Reina Valle R., Villena Manzanares F. (2013) Concentration of goods traffic in Spanish ports during the period 2000-2009. *Regional and Sectoral Economic Studies*, 13(2): 59-72.
177. Ribeiro da Silva F. (2017) The slave trade and the development of the Atlantic Africa port system, 1400s–1800s. *International Journal of Maritime History*, 29(1): 138–154.
178. Rimmer P.J. (1967a) Changes in the ranking of Australian seaports 1951–2 — 1961–2. *Tijdschrift voor Economische En Sociale Geografie*, 58(1): 28-38.
179. Rimmer P.J. (1967b) The changing status of New Zealand seaports, 1853–1960. *Annals of the Association of American Geographers*, 57(1): 88–100.
180. Rimmer P.J. (1967c) Recent changes in the status of seaports in the New Zealand coastal trade. *Economic Geography*, 43(3): 231–243.
181. Rimmer P.J. (2007) Port dynamics since 1965: Past patterns, current conditions and future directions. *Journal of International Logistics and Trade*, 5(1): 75-97.
182. Rimmer P.J., Comtois C. (2009) China's container-related dynamics, 1990–2005. *GeoJournal*, 74(1): 35–50.
183. Rodrigo González A., González-Cancelas N., Molina Serrano B. (2020) Preparation of a smart port indicator and calculation of a ranking for the Spanish port system. *Logistics*, 4(2): https://doi.org/10.3390/logistics4020009
184. Rodrigue J.P., Ashar A. (2016) Transshipment hubs in the New Panamax Era: The role of the Caribbean. *Journal of Transport Geography*, 51: 270–279.
185. Rodrigue J.P., Comtois C., Slack B. (1997) Transportation and spatial cycles: evidence from maritime systems. *Journal of Transport Geography*, 5(2): 87–98.
186. Rodrigue J.P., Notteboom T.E. (2010) Foreland-based regionalization: Integrating intermediate hubs with port hinterlands. *Research in Transportation Economics*, 27(1): 19–29.
187. Rousset L., Ducruet C. (2020) Disruptions in spatial networks: a comparative study of major shocks affecting ports and shipping patterns. *Networks and Spatial Economics*, 20(2): 423–447.
188. Sahu P.K., Padhi A., Patil G.R. (2019) Spatial temporal analysis of freight flow through Indian major seaport system. *The Asian Journal of Shipping and Logistics*, 35(1): 77–85.
189. Sánchez R.J., Wilmsmeier G. (2006) The river plate basin–A comparison of port devolution processes on the East Coast of South America. *Research in Transportation Economics*, 17: 185–205.
190. Santos T.A., Soares C.G. (2017) Development dynamics of the Portuguese range as a multi-port gateway system. *Journal of Transport Geography*, 60: 178–188.
191. Santos T.A., Soares C.G. (2019) Container terminal potential hinterland delimitation in a multi-port system subject to a regionalization process. *Journal of Transport Geography*, 75: 132–146.

192. Sdoukopoulos E., Boile M. (2020) Port-hinterland concept evolution: A critical review. *Journal of Transport Geography*, 86: 102775.
193. Shneerson D. (1981) Investment in port systems: A case study of the Nigerian ports. *Journal of Transport Economics and Policy*, 15(3): 201–216.
194. Shneerson D. (1983) Short term planning for a port system. *Maritime Policy and Management*, 10(4): 217-250.
195. Slack B. (1985) Containerization, inter-port competition, and port selection. *Maritime Policy and Management*, 12(4): 293–303.
196. Slack B. (1994) Domestic containerization and the load centre concept. *Maritime Policy and Management*, 21(3): 229–236.
197. Slack B. (1999) Across the pond: container shipping on the North Atlantic in the era of globalisation. *GeoJournal*, 48(1): 9–14.
198. Slack B., Starr J. (1997) Geostrategy, resources and geopolitics: implications for the US Navy and naval port system. *Marine Policy*, 21(4): 309–323.
199. Slack B., Wang J.J. (2002) The challenge of peripheral ports: an Asian perspective. *GeoJournal*, 56(2): 159–166.
200. Smith H.D., Pinder D. (1997) Geostrategy and naval port systems: frameworks for analysis. Marine Policy, 21(4): 291–308.
201. Smith H.D., Pinder D. (1998) Geostrategy, naval power and naval port systems. *Oceanographic Literature Review*, 1(45): 141.
202. Song S.C., Park S.H., Yeo G.T. (2019) Network structure analysis of a sub-hub-oriented port. *The Asian Journal of Shipping and Logistics*, 35(2): 118–125.
203. Spengler T., Tovar B. (2021) Potential of cold-ironing for the reduction of externalities from in-port shipping emissions: The state-owned Spanish port system case. *Journal of Environmental Management*, 279: 111807.
204. Stamatovic K., de Langen P.W., Groznik A. (2018) Port cooperation in the North Adriatic ports. *Research in Transportation Business and Management*, 26: 109–121.
205. Starr J.T. (1994) The mid-Atlantic load centre: Baltimore or Hampton roads? *Maritime Policy and Management*, 21(3): 219–227.
206. Sun Y., He W. (2008) A study on port cooperation in the Tianjin and Hebei areas using factor analysis. *Journal of Comparative International Management*, 11(2): 23–31.
207. Svindland M., Monios J., Hjelle H.M. (2019) Port rationalization and the evolution of regional port systems: the case of Norway. *Maritime Policy and Management*, 46(5): 613–629.
208. Taaffe E.J., Morrill R.L., Gould P.R. (1963) Transport expansion in underdeveloped countries: a comparative analysis. *Geographical Review*, 53(4): 503-529.
209. Talley W.K. (1988) The role of US ocean ports in promoting an efficient ocean transport system. *Maritime Policy and Management*, 15(2): 147-155.
210. Tavasszy L., Minderhoud M., Perrin J.F., Notteboom T.E. (2011) A strategic network choice model for global container flows: specification, estimation and application. *Journal of Transport Geography*, 19(6): 1163–1172.
211. Todd D. (1993) The interplay of trade, regional and technical factors in the evolution of a port system: the case of Taiwan. *Geografiska Annaler: Series B, Human Geography*, 75(1): 3–18.
212. Todd D., Zhang L. (1993) Political and technical factors impinging on port operations: The case of Manchuria. *GeoJournal*, 30(4): 441–454.
213. Trepte K., Rice Jr J.B. (2014) An initial exploration of port capacity bottlenecks in the USA port system and the implications on resilience. *International Journal of Shipping and Transport Logistics*, 6(3): 339–355.
214. Tuljak-Suban D., Twrdy E. (2015) Fuzzy empty containers excess estimation as an economic indicator—the case of the north Adriatic port system. *Maritime Policy and Management*, 42(8): 759–775.
215. Uderman S., Rocha C.H., Cavalcante L.R. (2012) Modernization of the port system in Brazil: a methodological proposal. *Journal of Transport Literature*, 6: 221–240.

216. Van Klink H.A. (1998) The port network as a new stage in port development: the case of Rotterdam. *Environment and Planning A*, 30(1): 143–160.
217. Van Thai V., Grewal D. (2005) An analysis of the efficiency and competitiveness of Vietnamese port system. *Asia Pacific Journal of Marketing and Logistics*, 17(1): 3-31.
218. Veenstra A., Notteboom T.E. (2011) The development of the Yangtze River container port system. *Journal of Transport Geography*, 19(4): 772–781.
219. Vermeiren T., Macharis C. (2016) Intermodal land transportation systems and port choice, an analysis of stated choices among shippers in the Rhine–Scheldt delta. *Maritime Policy and Management*, 43(8): 992–1004.
220. Vonck I., Notteboom T.E. (2016) Panarchy within a port setting. *Journal of Transport Geography*, 51: 308–315.
221. Walker A.R. (1989) Recessional and Gulf war impacts on port development and shipping in the Gulf States in the 1980's. *Geojournal*, 18(3): 273-284.
222. Wang B., Chin K.S., Su Q. (2022) Prevention and adaptation to diversified risks in the seaport–dry port system under asymmetric risk behaviors: Invest earlier or wait? *Transport Policy*, 125: 11-36.
223. Wang B., Chin K.S., Su Q. (2022) Risk management and market structures in seaport–dry port systems. *Maritime Economics & Logistics*, 24(1): 114–137.
224. Wang C., Ducruet C. (2012) New port development and global city making: emergence of the Shanghai–Yangshan multilayered gateway hub. *Journal of Transport Geography*, 25: 58–69.
225. Wang C., Ducruet C. (2013) Regional resilience and spatial cycles: Long-term evolution of the Chinese port system (221BC–2010AD). *Tijdschrift voor Economische en Sociale Geografie*, 104(5): 521–538.
226. Wang C., Wang J. (2011) Spatial pattern of the global shipping network and its hub-and-spoke system. *Research in Transportation Economics*, 32(1): 54–63.
227. Wang C., Wang J., Ducruet C. (2012) Peripheral challenge in container port system: A case study of Pearl River Delta. *Chinese Geographical Science*, 22(1): 97–108.
228. Wang J.J. (1998) A container load center with a developing hinterland: a case study of Hong Kong. *Journal of Transport Geography*, 6(3): 187–201.
229. Wang J.J., Ng A.K.Y. (2011) The geographical connectedness of Chinese seaports with foreland markets: a new trend? *Tijdschrift voor Economische en Sociale Geografie*, 102(2): 188–204.
230. Wang J.J., Slack B. (2000) The evolution of a regional container port system: the Pearl River Delta. *Journal of Transport Geography*, 8(4): 263–275.
231. Wang L., Lau Y.Y., Su H. (2022) Dynamics of the Asian shipping network in adjacent ports: Comparative case studies of Shanghai-Ningbo and Hong Kong-Shenzhen. *Ocean and Coastal Management*, 221: 106127.
232. Wang L., Notteboom T.E., Lau Y.Y. (2017) Functional differentiation and sustainability: A new stage of development in the Chinese container port system. *Sustainability*, 9(3): 328.
233. Wang L., Zhu Y., Ducruet C., Bunel M., Lau Y.Y. (2018) From hierarchy to networking: The evolution of the "twenty-first-century Maritime Silk Road" container shipping system. *Transport Reviews*, 38(4): 416–435.
234. Wang R., Yu G. (1997) The open port system in northeast China. *Chinese Geographical Science*, 7(3): 270–277.
235. Wang W., Wang C., Jin F. (2017) The functional structure convergence of China's coastal ports. *Sustainability*, 9(12): 2185.
236. Wang Y., Cullinane K.P.B. (2014) Traffic consolidation in East Asian container ports: a network flow analysis. *Transportation Research Part A*, 61: 152–163.
237. Wang Y., Cullinane K.P.B., Hu Y. (2014) The role of feeder shipping in Chinese container port development. *Transportation Journal*, 53(2): 253–267.
238. Wang Y., Yeo G.T. (2019) Transshipment hub port selection for shipping carriers in a dual hub-port system. *Maritime Policy and Management*, 46(6): 701–714.
239. Warf B. (1989) US imports of petroleum and related products in the 1980s. *Maritime Policy and Management*, 16(4): 265–275.

240. Warf B., Kleyn L. (1989) Competitive status of US ports in the mid-1980s. *Maritime Policy and Management*, 16(2): 157–172.
241. Westerholm J. (1986) The development of a national port system-Denmark 1950-1980. *Fennia-International Journal of Geography*, 164(2): 211–290.
242. Wiegmans B.W., Konings R., Priemus H. (2009) Critical mass for the development of a new container port in Vlissingen. *Maritime Economics & Logistics*, 11(4): 399–417.
243. Wiegmans B.W., Witte P., Spit T. (2015) Characteristics of European inland ports: A statistical analysis of inland waterway port development in Dutch municipalities. *Transportation Research Part A*, 78: 566–577.
244. Wilmsmeier G., Monios J. (2013) Counterbalancing peripherality and concentration: an analysis of the UK container port system. *Maritime Policy and Management*, 40(2): 116–132.
245. Wilmsmeier G., Monios J. (2016) Institutional structure and agency in the governance of spatial diversification of port system evolution in Latin America. *Journal of Transport Geography*, 51: 294–307.
246. Wilmsmeier G., Monios J., Farfán A.F.B. (2021) Port system evolution in Ecuador–Migration, location splitting or specialisation? *Journal of Transport Geography*, 93: 103042.
247. Wilmsmeier G., Monios J., Pérez-Salas G. (2014) Port system evolution–the case of Latin America and the Caribbean. *Journal of Transport Geography*, 39: 208–221.
248. Wilmsmeier G., Monios J., Rodrigue J.P. (2015) Drivers for outside-in port hinterland integration in Latin America: the case of Veracruz, Mexico. *Research in Transportation Business and Management*, 14: 34–43.
249. Wilmsmeier G., Notteboom T.E. (2011) Determinants of liner shippping network configuration: a two-region comparison. *GeoJournal*, 76(3): 213–228.
250. Wilmsmeier G., Sanchez R.J. (2017) Evolution of national port governance and interport competition in Chile. *Research in Transportation Business and Management*, 22: 171–183.
251. Wiradanti B., Pettit S., Potter A. (2018) Ports, peripherality and concentration–deconcentration factors: a review. *Maritime Business Review*, 3(4): 375-393.
252. Wiradanti B., Pettit S., Potter A. (2020) Willingness to invest in peripheral ports: Perceptions of Indonesian port and maritime industry stakeholders. *Maritime Economics & Logistics*, 22(4): 699–714.
253. Witte P., Wiegmans B., Ng A.K.Y. (2019) A critical review on the evolution and development of inland port research. *Journal of Transport Geography*, 74: 53–61.
254. Witters R.L., Ivy R.L. (2002) Port competition for cargo tonnage in the US South. *Southeastern Geographer*, 42(1): 65–80.
255. Wu X., Luo M., Zhang A. (2017) Do larger ships visit fewer regions/ports? An empirical analysis on global liners serving China. *Journal of Transport Economics and Policy*, 51(3): 173–192.
256. Xu M., Li Z., Shi Y. (2015) Evolution of regional inequality in the global shipping network. *Journal of Transport Geography*, 44: 1–12.
257. Xu Q., Huang T., Chen J. (2021) Port rank-size rule evolution: Case study of Chinese coastal ports. *Ocean and Coastal Management*, 211: 105803.
258. Yang D., Wang K.Y., Xu H. (2017) Path to a multilayered transshipment port system: How the Yangtze River bulk port system has evolved. *Journal of Transport Geography*, 64: 54–64.
259. Yang Z., Xiu Q., Chen D. (2019) Historical changes in the port and shipping industry in Hong Kong and the underlying policies. *Transport Policy*, 82: 138–147.
260. Ye S., Qi X., Xu Y. (2020) Analyzing the relative efficiency of China's Yangtze River port system. *Maritime Economics & Logistics*, 22(4): 640–660.
261. Yu M., Lee C.Y., Wang J.J. (2017) The regional port competition with different terminal competition intensity. *Flexible Services and Manufacturing Journal*, 29(3): 659–688.
262. Yu M., Shan J., Ma L. (2016) Regional container port competition in a dual gateway-port system. *Journal of Systems Science and Systems Engineering*, 25(4): 491–514.
263. Žgaljic D., Tijan E., Jugovic A. (2019) Implementation of sustainable Motorways of the Sea services multi-criteria analysis of a Croatian port system. *Sustainability*, 11(23): 6827.
264. Zhang Q., Yan K., Yang D. (2021) Port system evolution in Chinese coastal regions: A provincial perspective. *Journal of Transport Geography*, 92: 103031.

265. Zhang X., Lu J., Peng Y. (2022) Spatio-temporal evolution of the container port system along the 21st-century Maritime Silk Road. *Maritime Policy and Management*, https://doi.org/10.1080/03088839.2021.2017038
266. Zhao C., Wang Y., Gong Y. (2021) The evolution of the port network along the Maritime Silk Road: From a sustainable development perspective. *Marine Policy*, 126: 104426.
267. Zheng J., Shao B. (2022) Throughput properties and clustering analysis of coastal ports in mainland China: an analysis method by time series complex network. *DYNA-Ingeniería e Industria*, 97(4): 398-405.
268. Zografos K.G., Martinez W. (1990) Improving the performance of a port system through service demand reallocation. *Transportation Research Part B*, 24(2): 79-97.

Journal	No. articles
Maritime Policy and Management	38
Journal of Transport Geography	37
GeoJournal	13
Transport Policy	11
Maritime Economics and Logistics	8
The Asian Journal of Shipping and Logistics	6
Tijdschrift voor Economische en Sociale Geografie	6
Journal of International Logistics and Trade	5
Marine Policy	5
Research in Transportation Economics	5
Transport Reviews	5
Environment and Planning A	4
International Journal of Shipping and Transport Logistics	4
Journal of Digital Convergence	4
Sustainability	4
Transportation Research Part A: Policy and Practice	4
Economic Geography	3
Journal of Maritime Research	3
Chinese Geographical Science	3

Table 1.1 Top 20 journals by the number of publications about port systems

Year	Author(s)	Area	Concentration	De-concentration
1963	Taaffe et al.	Ghana, Nigeria	Inland corridors	-
1967	Rimmer	Australia	Railway and road connections	Specialization, outport development
1967	Rimmer	New Zealand	Internal accessibility	Local & national policies, commodity specialization
1969	Hilling	West Africa	Trade & economic growth	New port development
1977	Hilling	Ghana	Deep-water ports	-
1981	Hayuth	USA	Local market size, inland accessibility, site & situation, early adoption (container)	-
1986	Westerholm	Denmark	-	Evening out – division of labor
1988	Charlier	Belgium	Multifunctional ports	Specialized ports
1988	Hayuth	USA	-	Challenge of secondary ports
1988	Marti	Pacific	Load center development	-
1989	Hilling	England & Wales	Containerization, larger bulk ships	Hub-feeder system between southeastern small ports and Benelux
1989	Warf	USA	Petroleum products	Crude petroleum
1989	Miyajima & Kwak	Japan	Regulated competition	Container growth in the periphery
1991	Hayuth	EU & North Am.	Intermodal gateways	Multiple itineraries
1992	Gilb	Europe	European integration	-
1992	Kuby & Reid	USA	Containerization, larger ships & trains, computers	-
1995	Hoyle & Charlier	East Africa	Transport system integration	-
1997	Notteboom	Europe	-	Inter-range competition, Med hub development, traffic shift to med-size ports
1998	Wang	Hong Kong & China	Load center	Cross-border investments (HK) to the periphery (China)
1999	McCalla	North America	-	Shift from New York to middle ranked ports
1999	Hoyle	Kenya	Mombasa	Second deepwater port
1999	Chaudhury & De	India	-	Liberalization, increased competition
2000	Brunt	Ireland	Metropolization	National Development Plans, structural funds, maritime corridors
2002	Slack & Wang	Asia	-	Management & operational strategies of private / public bodies
2004	Memon & al.	New Zealand	Import trade	Export trade
2005	Notteboom & Rodrigue	Europe & USA	-	Port regionalization & offshore hub development
2006	Notteboom	USA & Europe	Inter-range structure (USA)	Balance (Europe)
2006	Notteboom	East Asia	-	Chinese growth, Japan stagnation
2007	Notteboom	Le Havre – Hamburg range	Stability	-
2008	Ducruet	Northeast Asia	External hub dependence, crisis & isolation	-
2009	Ducruet & al.	North Korea	Metropolization, trade reorientation, political crisis	-
2009	Jaja	Nigeria	Colonization, consolidation	-
2010	Notteboom	Europe	Strong concentration	Multi-port gateway regions
2010	Ducruet & al.	Northeast Asia	Hub centralization	-
2010	Le & Ieda	Northeast Asia	Centralized governance (Korea), concentrated development (China, Korea)	Decentralized governance (China, Japan)
2011	Veenstra	Yangtze River	Port regionalization	Early development stage
2011	Wang & Ng	China	Hub-and-spoke network	Multilayered network
2012	Wang & al.	Pearl River Delta	-	Peripheral challenge
2012	Wang & Ducruet	Yangtze River	Metropolization, national policies	-
2012	Ducruet & Notteboom	World	Throughput growth	-
2012	Fraser & Notteboom	Southern Africa	Political & economic stability	Containerization at new ports, corridors, expansion projects, regional Integration
2012	Li & al.	China & USA	Concentration 1995-2005	Overall de-concentration
2013	Liu & al.	Pearl River Delta	-	Multi-gateway port network

2013	Wang & Ducruet	China	Regional resilience	Increased no. of ports
2013	Wilmsmeier & Monios	UK	High concentration	Hub-feeder system between southeastern small ports and Benelux
2013	Reina & Villena	Spain	General cargo, containers	Bulks
2014	Pan & al.	China	-	Challenge of the periphery, multi-gateway port regions
2014	Wilmsmeier & al.	Latin America & Caribbean	Traffic growth, hub-and-spokes systems	Port devolution
2014	Grushevska & Notteboom	Black Sea	Low concentration	Low integration, shift of transshipment to Med
2016	Mohamed-Chérif & Ducruet	North Africa	Hub dependence (Tangier)	-
2016	Pham & al.	Vietnam	-	Location (upstream ports)
2017	Yang & al.	Yangtze River	Iron ore concentration	-
2017	Wang & al.	China	-	Functional differentiation
2017	Castillo & Valdaliso	Spain	Maintained top 10	De-concentration 1880-
2017	Wang & al.	Europe-Asia	Multi-hub spatial agglomeration	Functional differentiation, division of labor, polycentricity
2018	Nguyen & al.	Vietnam	-	Location, administration, strategic planning
2018	Grifoll & al.	Mediterranean	-	Eastward shift
2018	Krivoshchekov & al.	Russian Arctic	-	No competition
2019	He & al.	Yangtze River	Hinterland rivalry, primacy	Overcapacity
2019	Svindland & al.	Norway	Traffic growth	Sustained no. of ports
2019	Monios & al.	Comparative	-	Minimal sailing distance, suitable channel & berth depth, high capacity inland links
2019	Chlomoudis & Styliadis	USA	Ship size, alliances, global operators	-
2019	Michael	Nigeria	Location, hinterland coverage, port size	-
2020	Nguyen & al.	Southeast Asia	-	Market share growth at inefficient ports
2020	Rousset & Ducruet	Comparative	-	Peripheral growth, rerouting
2020	Liu & Ping	Pearl River Delta	-	Spatial spillovers, cooperation
2020	Liu & Yeo	Mediterranean	Westward shift (cruise)	-
2020	Lopez-Bermudez & al.	Spain	Vulnerability of small & specialized ports	-
2020	Feng & al.	Yangtze River Delta	-	Port integration
2020	Zhao & al.	China	Core-periphery structures	-
2021	De Oliveira & al.	World	Low mobility, higher impact of top ports vs. midsize ports	-
2021	Huang & al.	Yangtze River Delta	-	Multi-core development
2021	Feng & al.	Yangtze River Delta	-	Decentralization, regionalization, water depth, competition
2021	Xu & al.	China	Container	General cargo
2021	Iyer & Nanyam	India	-	Perfect competition
2022	Ducruet & Itoh	World	Innovation diffusion (steam, container)	-
2022	Ducruet	World	Traffic diversity	Traffic specialization
2022	Zheng & Shao	China	-	Chaotic competition
2022	Esteve-Perez & Gutierrez-Romero	Baltic Sea	Stability	German ports growth
2022	Li & al.	Pearl River Delta	-	Overcapacity, wasteful competition
2022	Zhang & al.	Maritime Silk Road	-	Growth of small & medium-sized ports, bifractal structure

Table 1.2 Port system concentration and de-concentration factors, 1963-2022

Project	Duration	Leader port	Partner ports
E-Harbours Electric	2010–2013	Zaanstad	Amsterdam, Antwerp, Malmö
Common Mediterranean strategy and local practical Actions for the mitigation of Port, Industries and Cities Emissions (APICE)	2010–2013	Venice	Barcelona, Genoa, Marseille, Thessaloniki
Green and Effective Operations at Terminals and in Ports (Green EFFORTS)	2012–2014	Bremen	Delft, Hamburg, Rotterdam, Sines, Trelleborg
Green Technologies and Eco-efficient Alternatives for Cranes and Operations at Port Container Terminals (GREENCRANES)	2012–2014	Valencia	Koper, Livorno
Managing the Environmental Sustainability of Ports for a durable development (MESP)	2012–2015	Genoa	Aqaba, La Spezia, Patras, Tripoli (Lebanon)
Smooth Ports	2014–2020	Hamburg	Livorno, Monfalcone, Nantes, Varna
Sustainable Urban Mobility in MED PORT cities (SUMPORT)	2014–2020	Trieste	Durrës, Igoumenitsa, Koper, Kotor, Limassol, Valencia, Thessaloniki
Developing Low carbon Utilities, Abilities and potential of regional entrepreneurial Ports (DUAL Ports)	2015–2021	–	Emden, Hvide Sande, Niedersachsen Ports, Ostend, Skagen, Vordingborg, Zwolle
CIVITAS PORTIS	2016–2020	Antwerp	Aberdeen, Constanța, Klaipėda, Trieste
PORT-Cities: Integrating Sustainability (PORTIS)	2016–2020	Antwerp	33 European Union (EU) port cities
LOOP-Ports project (Circular Economy Network of Ports)	2018–2020	Valencia	32 EU port cities
SUstainable Ports in the Adriatic–Ionian Region (SUPAIR)	2018–2020	Trieste	Thessaloniki
Port IoT for Environmental Leverage (PIXEL)	2018–2021	Valencia	Bordeaux, Gorizia, Monfalcone, Piraeus, Rijeka, Thessaloniki, Trieste
CLean INland SHipping (CLINSH)	2016–2022	–	Antwerp, North Sea Port
Towards a Green and Sustainable Ecosystem for the EU Port of the Future (PortForward)	2018–2022	–	Kristiansand, Magdeburger Hafen, Northern Tyrrhenian Sea Port Authority System, Ports de Balears, Vigo
Assessment of Climate Change in Ports of Southwestern Europe (ECCLIPSE)	2019–2022	Valencia	Aveiro, Bordeaux
SUStainable PORTs (SUSPORT)	2020–2022	Trieste	Ancona, Central Adriatic, Chioggia, Dubrovnik, Ploče, Ravenna, Rijeka, Southern Adriatic, Split, Venice, Zadar
Green C Ports	2019–2023	Valencia	Chioggia, Piraeus, Venice
Operational Platform managing a fleet of semi-autonomous drones exploiting GNSS [Global Navigation Satellite System] high Accuracy and Authentication to improve Security & Safety in port areas (PASSport)	2020–	Kołobrzeg	Hamburg, Le Havre, Ravenna, Valencia

Table 1.3 Cooperation projects on sustainability among European ports, 2010-2023

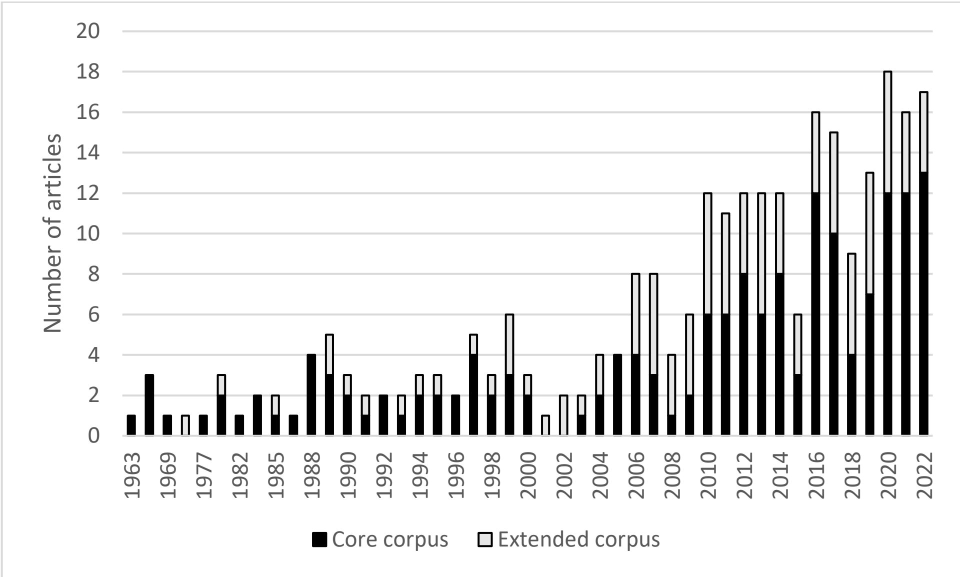

Figure 1.1 Publication trend of port system articles, 1963-2022

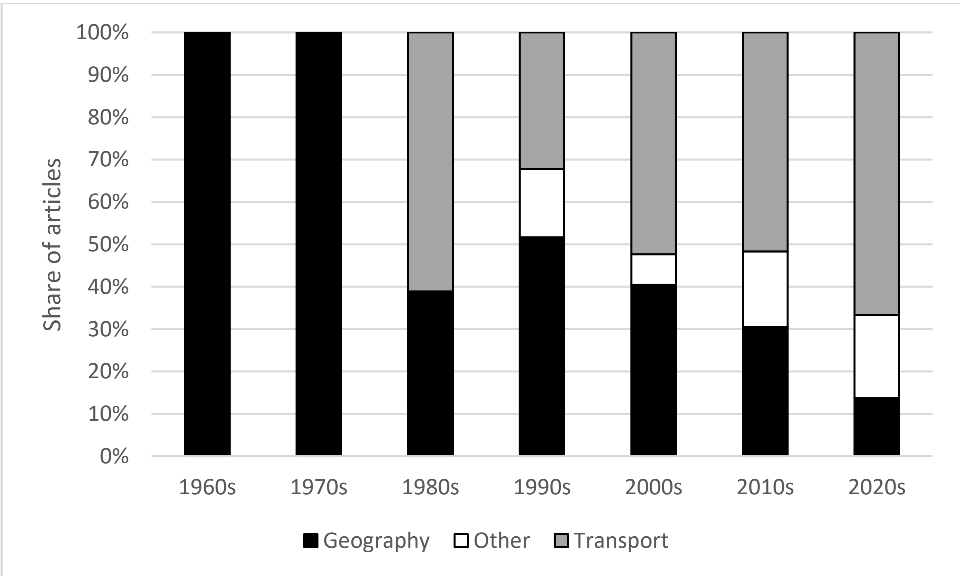

Figure 1.2 Distribution of articles by journal background, 1963-2022

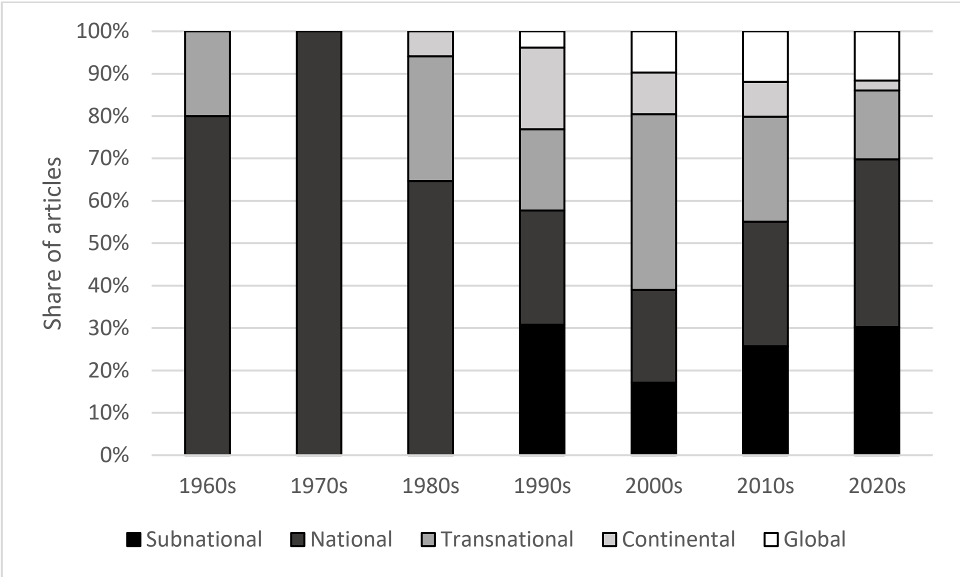

Figure 1.3 Distribution of articles by level of analysis, 1963-2022

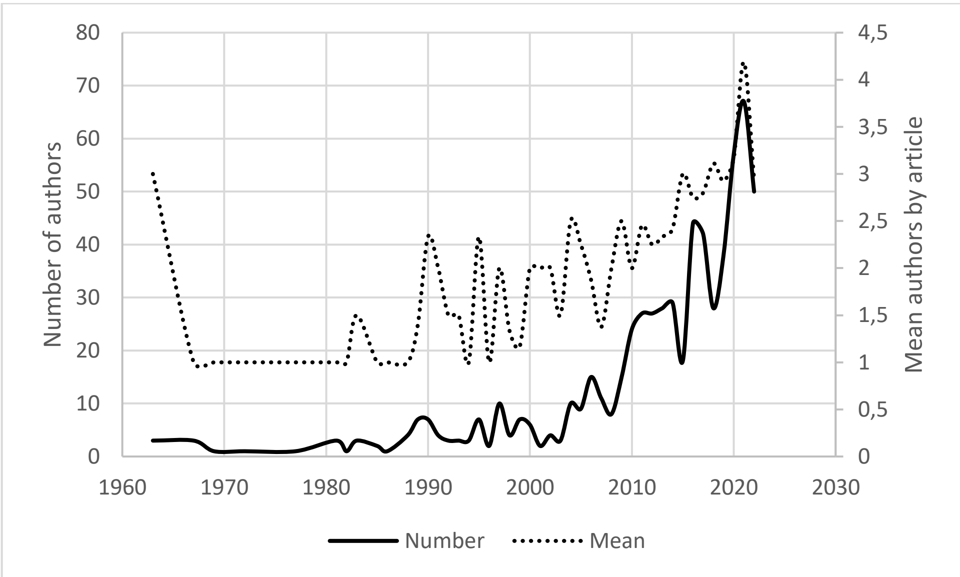

Figure 1.4 Collaboration dynamics, 1963-2022

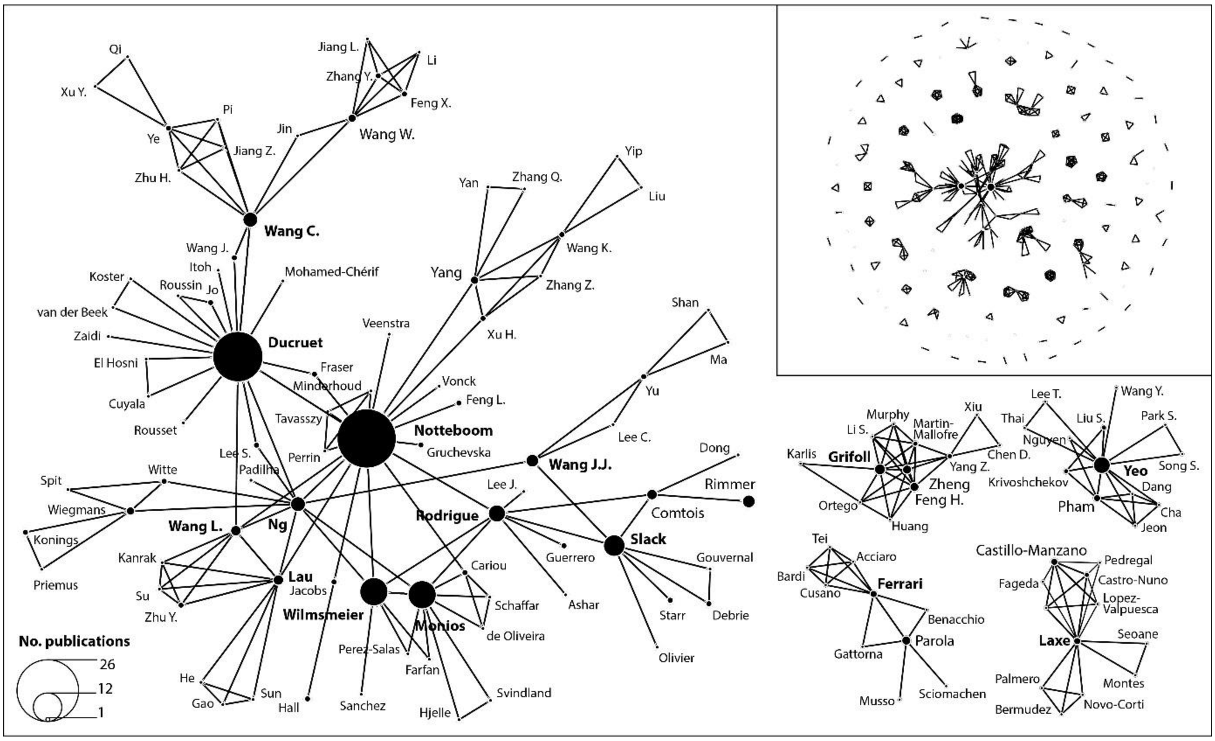

Figure 1.5 The co-authorship network of port system studies

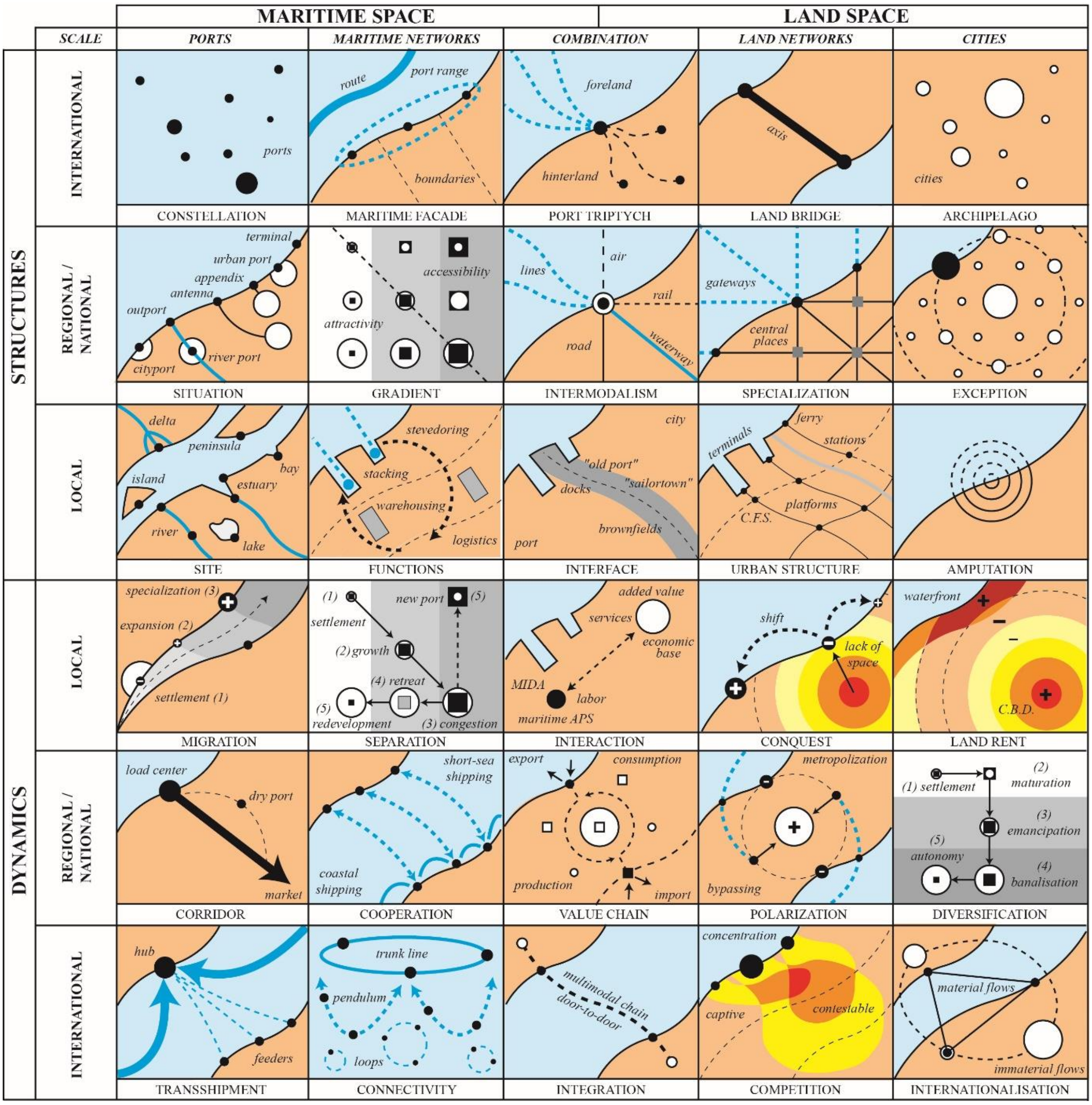

Figure 1.6 A multi-level modeling of ports and port systems

Source: adapted from Ducruet (2005)