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Maritime networks as systems of cities: The long-term interdependencies between global shipping flows and urban development (1890–2010)

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1. Introduction

Social sciences and humanities witnessed a growing emphasis for material flows, after decades of devotion to immaterial flows connecting people and places (O'Connor, 2010; Hall and Hesse, 2012; Kennedy et al., 2015; Urry et al., 2015). Maritime transport is one of the oldest forms of interaction across the Earth, and still supports more than 90% of international trade volumes nowadays. Despite its pioneering role in mapping maritime routes and flows since the 1940s, human geography later shifted its central focus towards land-based issues and people mobility. In parallel, ports and maritime transport increased their efficiency at the expense of their ties with cities and regions. The analysis of untapped maritime data in an urban context concludes to the permanency of strong port-city interdependencies, while it underlines the specific character of maritime transport as a looking glass and vital element of urban development.

Across the vast array of urban studies in economic geography and elsewhere, the urban network or "system of cities" has been the focus of numerous schools of thought, but without a clear definition of its functions and properties (Peris, 2016). How and why cities connect each other through various communication networks is thus another level of complexity. Despite its crucial role for trade and economic development (Bernhofen et al., 2013) and the growing concentration of world population along coastlines (Noin, 1999), maritime transport had not been studied yet from an urban network perspective. The Hanseatic League and the Italian and Asian city-states are classic examples of such systems, but a quantitative analysis of cities connected through shipping flows remains missing in economic geography. The well-known work of Braudel (1979) on major (maritime) cities being centers of functional world regions supported the idea that seas and oceans facilitate rather than constrain human interactions (Lewis and Wigen, 1999). Numerous monographs and models on ports, port cities, and maritime networks cannot remedy such a deficiency.

Maritime trade, and especially container shipping, went through faster growth than world GDP, exports, or population since the 1970s (Rodrigue et al., 2017), with important spatial and governance effects. Yet, cities and commodity flows are still interdependent today (Hall and Hesse, 2012), just like seaports and urban areas continue to share important mutual relationships at the local level (Hesse, 2013, 2017). Immaterial or virtual flows as well as other transport modes cannot replace the gigantic quantities of products carried by ships across the globe. A number of so-called global cities like Paris, London, Taipei, and Jakarta are currently reinforcing their port functions through huge investments in new container terminals near the urban core (El Hosni, 2017), after decades of economic diversification through successive innovation cycles (Pumain et al., 2009).

This paper has three main ambitions. First, we would like to fill the gap between two separate worlds, namely urban network research and maritime network research, which would benefit from a unified theoretical or empirical background. Second, we provide the first-ever empirical analysis of 120 years of global maritime flows in relation with urban development. This analysis addresses the degree to which urban and port hierarchies are interdependent, and investigates the changing influence of city sizes on the nature and intensity of maritime interactions. Such a long time-span is rather rare in urban and network studies, especially in the field of complex and spatial networks that increasingly seek to understand dynamic graphs. Lastly and thirdly, confronting maritime flows to both city and network is expected to improve our understanding of this particular industry, and how its spatial evolution and connectivity differ from other types of interactions.

The remainders of the paper are as follows. The next section introduces the theoretical background on cities and communication networks in economic geography and various disciplines. The third section presents the data and methodology allowing a new analysis of the interdependencies between urban development and maritime flows, based on untapped historical shipping records. The core of the paper lies in the fourth section where the application of several network analytical tools to the temporal matrix of interurban maritime flows reveals a number of trends and invariants. The conclusion discusses the contribution of this research to both urban, network, and maritime studies.

2. Theoretical background: Urban networks in economic geography and beyond

The concepts of "systems of cities" and "urban networks" have long

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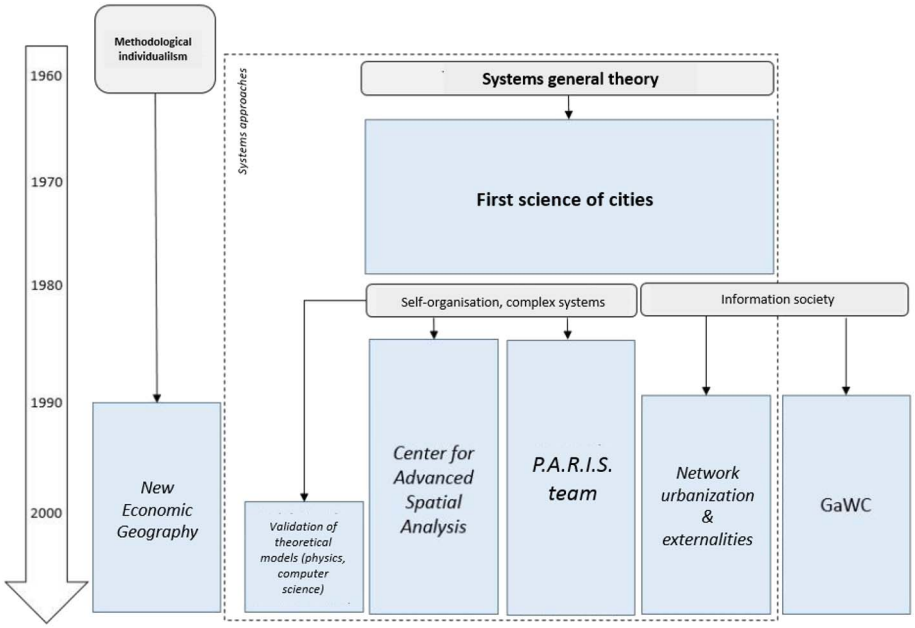

Fig. 1. Evolution of schools of thought about systems of cities.
Source: adapted from Peris (2016).

been discussed in geography and beyond. The review of this field by Peris (2016) underlined the existence of numerous self-proclaimed schools of thought and paradigms since the 1950s to nowadays. However, these approaches are often characterized by a rarity of theoretical explanations, and a wide diversity of definitions of the same object. This section is an attempt to recall and synthesize the main messages of such studies, without pretending to be exhaustive.

2.1. From the "First Science of Cities" to the "new paradigms"

The concept of urban network or system of cities dates back to the work of Jean Reynaud in the 1840s (see Robic, 1982), later formalized by Christaller (1933) in his central place theory, which defined regularities shaping urban hierarchies at different spatial scales. The *First Science of Cities* of the 1950s–1970s (Berry and Wheeler, 2014), combining the Anglo-Saxon and Swedish schools (Fig. 1), shifted the focus from urban morphology and internal structure to inter-urban patterns. According to such a horizontal approach (or *New Geography*), systems of cities necessitate complementarity, economic opportunity, and distance (Ullman, 1954; Berry, 1964), with the main hypothesis that changes in economic activities, professional structure, wages, and population in one city will affect others (Pred, 1977). These schools had in common to maintain a close link with regional planning issues, to produce numerous empirical studies of various types of flow matrices (e.g. phone calls, migrations, airlines), with reference to graph theory in the U.S. (Nystuen and Dacey, 1961; Törnqvist, 1968) or to the hierarchical diffusion of innovations (Hägerstrand, 1953; Pred, 1973). Hierarchical tendencies dominated notwithstanding the possibility for transversal linkages to emerge.

Until the early 1980s, a consensus existed about the system of cities concept, backed by numerous empirical studies based on population and socio-economic indicators. From such a core theory, different schools emerged. In France, the U.S. influence gained ground and led to a number of analyses at the national level investigating the relationship between hierarchy and specialization (Pumain et al., 1989). It also linked the urban network concept with synergetics (Sanders, 1992), evolution theory (Pumain, 1997), and provided empirical applications with reference to co-evolution (Paulus, 2004), space-time contraction, hierarchical diffusion, with an increasing use of simulation and agent-based models over long time-periods, the population of urban centers and their employment structure being the main empirical material. Although the *New Science of Cities*' main focus had been the intra-urban spatial organisation, the Centre for Advanced Spatial Analysis (CASA) in U.K. concentrated its efforts on the micro-level of agents from a more bottom-up perspective by which fractal structures emerge (Batty and Longley, 1994) with no "hidden hand" (Xie, 1996), with a similar taste for cellular automata and simulation. A third school focused on polycentric and reticular organizations, with a strong reference to the work of Gottmann (1961) on the megalopolis, particularly investigated the emergence of districts and clusters, based on the city network paradigm (Capello, 2000) and centered around the firm (Camagni and Salone, 1993). They particularly underlined the growth of distance for information exchanges, the multiple location of service firms, exploring key notions of which complementarity, vertical integration, synergy, arguing that connectivity had a stronger influence than size in urban networks (see Pflieger and Rozenblat, 2010).

In the meantime, two other schools developed their own vision of the urban network. The *Globalization and World City (GaWC) Study Group and Network* emerged in the early 2000s, mainly based on the theoretical approaches of Friedmann (1986) and Sassen (1991) about the so-called *global city* and on the *space of flows* (Castells, 1996). Numerous empirical analyses of the co-location of Advanced Producer Services (APS) in global cities were provided through the benchmarking method of interlocking network model consisting in ranking cities according to their composite connectivity score in such networks. This approach is also a critique to the central place theory bound to the urban/rural nexus, with a preference to the *central flow theory* (Taylor et al., 2010) promoting international versus local linkages. The *World City Network* had been studied in such ways, also with reference to complementary concepts such as Global Production Networks and Global Value or Commodity Chains (Coe et al., 2004; Gereffi and Korzeniewicz, 1994; Derudder and Witlox, 2010). A radically different approach came out with the *New Economic Geography* (NEG) based on the pioneering article by Krugman (1990), arguing that space matters in the location of firms. Related works especially investigated micro-economic theory to demonstrate the emergence of urban hierarchies and core-periphery patterns through the action of rational agents in a context of free market, cities connecting beyond national boundaries (Fujita et al., 1999). A plethora of related empirical applications, as in regional science (Reggiani, 2017), put transport costs at the core of the analysis of mainly road networks between cities (see Duranton et al., 2014). Lastly, the Evolutionary Economic Geography school considered