Material flows and local economic structure: port-region linkages in Europe, Japan, and the United States

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Abstract

The main goal of this paper is to identify mutual influences between the specialization of traffics passing through seaports and the socio-economic characteristics of their surrounding regions. While the contemporary era is marked by the fading spatial fix of value chains as notably seen in the dereliction of port's local linkages, a systematic and comparative empirical analysis remains lacking. One main reason is the absence of internationally harmonized data on the precise spatial distribution of port-related hinterland flows as well as inadequacies between the volume and the value of freight. This research proposes to overcome such difficulties based on a common set of 21 traffic and socio-economic indicators covering 189 port regions in Europe, Japan, and the United States. Main results underline invariants as well as local specificities in the functional and spatial affinity between certain traffics and certain types of regions. While large urban and financial centres tend to polarize most valued, diversified, and weighty traffics, rural regions generally concentrate agricultural goods and minerals, and industrial regions concentrate combustibles and metals. Beyond the simple reflection of local demand, such results confirm the path-dependency of the association between material flows and regional economic development. A typology of port regions is proposed in order to map the distribution of port regions and to zoom on specific local conditions.

Keywords: freight flows; port traffic; regional development; typology; value chain

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1. Introduction

Contemporary transport systems are marked by a dematerialization of the economy and rising average transport distances thereby making it increasingly difficult for decision-makers and scholars to map and explain the distribution of firms and flows in relation to their spatial environments (Leslie and Reimer, 1999; Hesse and Rodrigue, 2004). Continuous progress in the physical and organisational connectivity of transport systems as well as reduced trade barriers and logistics costs fostered the spatial volatility of flows, resulting in both concentration and diffusion of markets and flows across regions and nations (Fujita et al., 1999; Hesse, 2010). As noted by Janelle and Beuthe (1997), the absence of disaggregated data on detailed flows has often been a major obstacle to the analysis of their spatial determinants. Conversely, most research on transportation networks focuses dominantly on freight movements, capacity and connectivity problems in abstract spaces (e.g. graph theory, complex networks, routing and modelling), and carriers' strategies, with minor attention paid to the (changing) socio-economic characteristics of localities (Ducruet and Lugo, 2012). Such state of affairs also relates with the persistent divide between qualitative and quantitative approaches within transport geography as well as the difficulty identify underlying causal structures (Goetz et al., 2009).

Recent efforts have, however, expanded the understanding of the spatial fix of flows as well as the role of local economies in shaping such flows. It was found, for instance, significant correlation between the volume of air flows and the demographic and economic attributes of airport cities in various contexts (Neal, 2011; Dobruszkes et al., 2011; Wang et al., 2011) as well as strong interdependences between the pattern of communication flows and the well-being of localities (Eagle et al., 2010). Similar empirical research on maritime flows remains far less developed due to the drastic lack of data on land-based, hinterland freight flows that would enable the delineation of regions containing most port users (Darnton, 1963; McCalla et al., 2004; Guerrero, 2010). Assembling and analyzing port traffic and socio-economic data on port regions on the level of three large economic areas (namely Europe, Japan, and the United States) is proposed in this paper as a means to complement such statistical lacks and methodological difficulties. Technological, managerial changes in shipping and ports as well as the reorganization of hinterlands may not have fully eroded the spatial fix of freight flows, notably in relation with the adjacent territory or port region. Revealing such linkages might prove useful for the explanation of traffic distribution across space. The extent to which the structure of freight flows reflects - at least partly - the nature of adjacent economies also raises important methodological issues of data and geographic relevance, which will be explored further in the following sections.

The remainder of this paper is as follows. Section 2 offers a discussion on the nature of port traffic, with regard to specific commodities, locations, and the problem of transit flows when trying to assign such traffic to particular places. Section 3 introduces the data and methodology used to compare the mutual specialization of port traffic and local economies in Europe, Japan, and North America. Section 4 describes the main trends obtained from a Principal Components Analysis (PCA) and hierarchical classification of port regions. Finally, Section 5 discusses the implications of the results for port policy and regional planning as well as prospects for further research in the field.

2. Background and issues in port-region linkages

The port region remains a rather fuzzy concept broadly defined as the "immediate hinterland" of the port where most of its clients and port-related activities are located (Vleugels, 1969; Ducruet, 2009). Although ports are traditionally seen as strategic gateways conferring distinct characters to their territories compared with those of central places (Bird, 1983), more recent evidences depict a dereliction of ports' local linkages (Hoare, 1986; Todd, 1993; Campbell, 1993; Vallega, 1996; Musso et al., 2000). Many large ports, however, have maintained their activities through rapid and profound transformations (Lee and Ducruet, 2009; Wang and Cheng, 2010; Hall and Jacobs, 2012). While ports have been largely left aside by regional development literature (Hall, 2002), the local economy has been ignored in studies of port selection factors (Ng, 2009) and of the added value of port traffics (Charlier, 1994; Haezendonck, 2001). Discussions on port-related local economic growth provide either general views and models (Stern and Hayuth, 1984; Fujita and Mori, 1996; Haddad et al., 2005) or in-depth case studies lacking comparability such as those about port impacts (Hall, 2004a). Most of the time, research is unidirectional by looking at how port and maritime activities influence and impact local economic development while it ignores how the latter influences and impacts the first.

Although it has always been difficult to measure the benefits of port activities to local economies (Bird, 1971) especially in a comparative perspective, some recent studies have provided a number of empirical results supporting the idea of lowering but maintained port-region linkages. Both quantitative (De Langen, 2007) and qualitative (McCalla et al., 2001) approaches have revealed a lack of linkages between port activities and their adjacent economies in the United States and Canada. Port regions also appeared poorer than other regions in Europe (Lever, 1995) and the United States (Grobar, 2008; Hall, 2009) in terms of regional GDP per capita and average wage levels. Another set of studies pointed, however, at noticeable interdependencies between local economies and traffic dynamics. The size and diversity of urban economies adjacent to ports influences to some degree the size and diversity of port traffics in the United States (Carter, 1962) and in Europe (Ducruet et al., 2010), while smaller ports are often more specialized and bound to local industries (Kuby and Reid, 1992).

One very important aspect of port-region linkages is the influence of the local setting or context. For instance, the correlation between total port throughput and the demographic weight of port cities has dramatically lowered on a global level since the 1990s but it has maintained or even increased in specific regions such as Oceania and North America (Ducruet and Lee, 2006), due to the diversity of urban-port trajectories, port systems configurations, and hinterland spatial patterns (Lee et al., 2008; Rodrigue and Notteboom, 2010). As seen in Figure 1, different geographical areas exhibit contrasted hinterland spatial patterns, notably due to the uneven balance between coastal and inland locations in terms of economic concentrations and transport network connectivity. Europe is more characterized by an inland concentration of core economic regions as opposed to Asia and North America, although the latter has also developed continental connections through intermodal transport. One direct implication of such configurations is the varied importance of transit flows at seaports and hence, a different meaning of port-region linkages depending on the local context. In China, gross regional product, amount of Foreign Direct Investment, and industrial productivity had a positive influence on port traffic growth during the 1995-2007 period (Cheung and Yip, 2011). Across OECD countries and during the same period, regional specialization in the industrial and tertiary sector had a negative and positive influence respectively on the volume and growth of container port throughputs (Ducruet, 2009). The weak linear correlation between port traffic volume and the number of firms in port-related sectors has been confirmed globally (Jacobs et al., 2011) but without contradicting the fact that certain specialized gateways keep concentrating both tertiary activities and traffics, such as Rotterdam and Houston (Jacobs et al., 2010).

While most existing studies neglect the diversity of port traffics, another central argument of this research is that different cargo types will have different affinities with the outlying region where port traffic takes place (Haefner et al., 1980; Marti, 1985), as seen in the example of port-industry complexes processing imported raw materials for local transformation, such as petrochemicals (Rodrigue et al., 2009; Dunford and Yeung, 2009), and in the case of automobile imports (Hall, 2004b). Indeed, there are wide differences among commodities passing through seaports in terms of travelled distance and spatial friction as demonstrated by Debrie and Guerrero (2008) on the French case. One major difficulty is that one same port may handle a combined set of commodities serving multiple industries inside and outside the port region. However, such functional and regional differences that are known in practice were not sufficiently tested empirically based on comparable data and rigorous statistical methods.

[Insert Figure 1 about here]

3. Data and methodology

3.1 The contours of port regions

One first step was to select economically and spatially relevant local units that would be comparable across Europe, Japan and the United States. A trade-off between their number and size resulted in a selection of 115 NUTS-2 regions (Europe, 16 countries), 39 prefectures (Japan), and 35 States (United States) recording port traffic in the year 2008 and for which comparable socio-economic data was available. We are aware of the limits of such arbitrary definitions, which do not always match the true extent of port hinterlands and/or port regions. The work of Patton (1958) on general cargo hinterlands in the United States clearly recalled the difficulty delineating such regions and the fact that large ports handle large volumes destined to / originating from distant areas, thus with no relationship with local industries, and depending on the directionality (i.e. imports vs. exports) as well as intermodal arrangements (i.e. rail). For instance, it was estimated that 70% of Marseilles' port traffic in 1900 was destined to local industries (Garnier and Zimmermann, 2004), while more recently, 75% of New York's port traffic was generated and consumed within a 300 mile radius from the port (Rodrigue, 2003). The urban areas of Bordeaux (France) and Busan (South Korea) accounted for only 15% and 10% of respective port traffics in recent years (source: port authorities). Customs data notably allows calculating the share of the adjacent region in total port traffic (Table 1): in 2005, French coastal regions (*départements*) surrounding ports were responsible for 63% and 18% of French total traffic volume and value respectively (Ducruet, 2011). Such imbalance between volume and value directly translates the polarization of most valuable flows by the Paris capital region and other large inland cities. Larger ports tend to handle higher transit traffics than smaller ports due to the wider spatial extent of their hinterlands, especially for Le Havre, Paris' main gateway. Traffic is thus inflated by transit flows either landward (i.e. road, rail, river, pipeline, air-sea) or seaward (i.e. coastal and short-sea shipping, transhipment, and feedering). The fact that about 40% of French exports pass through Antwerp and other Benelux ports is a good example of such detours (Gouvernal et al., 2010). For Le Havre, about one-third of its container traffics relate with the Greater Paris region (source: port authority). The share of transit flows varies from one port to another depending on their specialisation in hinterland and/or hub functions. Hinterland ports may also be maritime hubs, such as Rotterdam (30% transhipment), while others stand as "pure transhipment hubs" due to the absence of a local cargo base, such as Gioia Tauro in Calabria. Yet, transit flows are not entirely disconnected from the local economy since they create the need for additional activities and infrastructures (e.g. warehousing, packaging), but not every large port has been able to create such value-added. Even a large coastal metropolis may prefer distant port terminals than its own due to problems of congestion and negative environmental impacts locally.

[Insert Table 1 about here]

The choice of administrative regions was motivated by the availability of socio-economic data and by the fact that those regions remain large enough to contain a majority of port-related activities composing the so-called port cluster (De Langen, 2004). While in some cases the regional unit is too small (e.g. the Lander of Hamburg) or too large (e.g. California including Los Angeles, Oakland, and other ports) in comparison with hinterlands, it still has relevance in terms of the location of activities directly related with the port. Large ports located within such urban areas will thus be amputated in terms of hinterland coverage. This is particularly true for containers due to the inland shift of many logistics and distribution activities during the current "port regionalization phase" (Notteboom and Rodrigue, 2005). Among European port cities for instance, it is often the case that a large proportion of transport activities locate in suburban areas (Ducruet and Lee, 2007). Nevertheless, administrative regions remain highly relevant to test the influence of large cities on traffic flows, because port-region linkages are not only about physical transfers but also refer to immaterial interdependencies, such as within the tertiary sector, which locate in or close to the Central Business District (CBD) near the port.

3.2 The choice of port traffics

The nature and level of economic specialization of such regions was measured on the level of six employment sectors based on various data sources (see Table 2)[2]. In addition to these core variables were added regional GDP, unemployment, population size and population density as proxies for market size and economic wealth. Each regional indicator was calculated as a location quotient based on the national average (e.g. percentage of primary sector employment in total employment of region i divided by percentage of primary sector employment in total employment of the country), except for demographic size and population density (i.e. score of region i divided by mean score of all regions). Mixing regional indicators and port traffic indicators, of course, has the "*risk of attributing to port-related differences what are in fact differences in regional economic structure*" (Hall, 2002).

Traffic data of individual ports located within the same administrative region was summed by main category in order to have the same number than for employment variables. Original sources were in fact dissimilar by their number of detailed traffic categories and their classification methods[3]. From the 18 categories provided by Eurostat, containers were counted as manufactured goods although their detailed content is unknown and may include other commodities such as neo-bulks, while some other traffic categories are not fully explained:

[2] The principal data sources are Eurostat for Europe, the Annual Report on Prefectural Accounts (Cabinet Office of the Government), the Labor Force Survey, Employment Structure Basic Survey, and National Population Census (Statistics Bureau, Ministry of Internal Affairs and Communications) for Japan, the Bureau of Statistics and the OECD Territorial Database for the United States.

[3] Data sources used to measure port traffics are Eurostat for Europe, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) for Japan, and the Army Corps of Engineers for the United States.

other dry bulk, other liquid bulk, and other general cargo. In comparison, the 81 and 146 commodities for Japan and the United States respectively were more easily classified into six common categories. While each traffic category corresponds to specific products, the precise link with the aforementioned economic sectors may not be obvious, due to the impossibility distinguishing imports from exports for each commodity. For instance, manufactured goods that are generally containerized have links with multiple sectors depending on the context, such as manufacturing (e.g. export), retail (consumption), and transport/logistics (e.g. warehousing, distribution) (Van der Lugt and De Langen, 2005). The same type of raw materials can be handled within very distinct local economies depending on if it is exported (e.g. cereals exported from an agricultural region) or imported (e.g. cereals imported from a manufacturing region). In addition, some ports have widened their commodity mix through successive (and often path-dependent) diversification phases. Many modern container ports are or have been heavy industrial complexes, as seen in South Europe for instance with the close overlap between main container hubs and former petrochemical and steelwork sites such as Sines, Huelva, Cagliari, Gioia Tauro, and Taranto. Each of the six commodity categories was transformed into a location quotient as follows: percentage of combustibles traffic in total traffic of region i divided by percentage of combustibles traffic in total traffic of the country/continent.

A few other traffic variables were calculated to complement the analysis of specialization, such as traffic size, international traffic (i.e. extra-EU27 for Europe), inbound traffic, level of commodity diversity, and level of spatial friction. International and inbound traffic provide information on the extent of port activities and their directionality, while traffic size expresses the overall performance of the port region in accumulating physical flows. International and inbound traffics were changed to indices based on the same method than for commodity categories (i.e. percentage of international traffic in total port traffic of region i divided by percentage of international traffic in total port traffic of the country/continent). Traffic size is simply a ratio between the total port traffic of each region and the average traffic of all regions. The level of commodity variety was proposed by Ducruet et al. (2010) in order to reflect the capacity of a given port (or region) to handle multiple flows. It is calculated for each port region as the inverse of the sum of absolute differences in commodity shares at country/continent level. Higher values point at more diversified ports and lower values underline strongly specialized port regions. The level of spatial friction was derived from the work of Debrie and Guerrero (2008) on French port hinterlands. Their analysis applied a spatial interaction model on customs data on the amount of transported freight by commodity types to/from seaports within the country in order to estimate the role of distance on the volume of port-related flows. They particularly demonstrated that in general, manufactured goods travel longer distances than liquid and dry bulks. Each of the six traffic categories was weighted according to their results by commodity-specific parameters[4]. This indicator particularly highlights which commodities are more likely to remain produced, consumed, and/or processed within the port region (captive hinterland) as opposed to more mobile commodities reaching farther markets (contestable hinterlands). The traffic of each port region was then weighted by calculating the share of distance-constrained traffic in total port traffic (spatial friction index).

[Insert Table 2 about here]

4. Traffic specialisation and regional specialisation

4.1 Main trends

The comparison of correlation coefficients among all variables at each area allows a first understanding of the main trends affecting port-region linkages (Figure 2). Pearson and Spearman correlations are compared given the different statistical distribution of variables. The main trend for Japan is a coincidence between traffic volume, manufactured goods, and a profile of large, densely populated, richer, and tertiary regions. It underlines the closeness between urban hierarchy and port hierarchy for the most valued goods. Other traffics have limited correlation with regional indicators, except for the slightly significant ones between the agricultural sector and minerals traffic. Most other significant correlations occur either among traffic variables or socio-economic variables, such as metals and traffic volume, combustibles and international traffic. Spearman correlations provide a similar picture, with the exception of metals traffic with population density, and international traffic with the industrial sector and regional GDP. For the United States and Europe, correlations remain rather moderate compared with Japan, thereby suggesting a lower statistical significance of port-region linkages in those areas. The highest positive correlation for the United States occurs between traffic volume and demographic size, followed by manufactured goods traffic

[4] The weighting value for each commodity type corresponds to the share of variance (%) explained by distance and has been measured as follows: 30.1% for manufactured goods, 53.7% for chemicals, 57.1% for minerals, 67.9% for metals, 75% for agricultural goods, and 92% for combustibles.

and the financial sector, metals traffic and the retail sector, agricultural goods traffics and the agricultural sector, international traffic and the construction and financial sectors. Moreover, Spearman correlations show some strong relationships between public services and combustibles, chemicals and diversity, and agricultural and metal products. Despite some differences, such trends are comparable with Japan due to the proximity between large traffics of higher valued goods, the tertiary (finance and real estate) sector, and population. Japan and the United States have indeed in common to concentrate container traffics at major urban centres that also concentrate higher-order economic functions. In the European case, Pearson correlations are rather insignificant and cannot account for tangible port-region linkages as in the previous cases. This is partly solved by looking at Spearman correlations based on ranks rather than initial values. Similar trends thus emerge, such as the closeness between manufactured goods traffic, the financial sector and population density, while demographic size is positively and significantly correlated with traffic volume, traffic diversity, and international traffic, but also chemicals and metals. It thus confirms that among the three areas considered, the nature of port-region linkages remains similar as most voluminous and valued goods concentrate at tertiary and populated regions. Although the statistical significance differs greatly, the nature of port-region linkages is comparable thus supporting the idea of invariants in the geography and locational factors of port traffics.

[Insert Figure 2 about here]

The application of a Principal Components Analysis (PCA) on each of the three datasets provides some answers to the initial hypotheses (Table 3). Results for Japan exhibit higher statistical significance, followed by the United States and Europe, thereby reflecting upon their respective spatial configurations. Due to the presence of many different countries and to the continental character of hinterlands in Europe, its cumulated variance reaches only 51% at the fourth principal component, compared with 59% for the United States and 71% for Japan. The lower score of the United States compared with Japan is also explained by the fact that some ports serve more distant hinterlands than their adjacent regions, notably through extensive intermodal services such as by railways. It may thus be interpreted that port-region linkages have weaker significance in Europe compared with other regions. Nevertheless and despite such differences, port-region linkages share similar trends across the three areas as discussed in the following sections and based on Figure 3. A hierarchical clustering was applied to the four main principal components in order to establish a typology of port regions in each area, where the best represented port regions in each cluster is highlighted.

[Insert Table 3 about here]

[Insert Figure 3 about here]

4.2 Europe

European port regions are characterized by an affinity between minerals, metals, agricultural goods and the agricultural, construction, and industry sectors (PC1). This constitutes a rather logical association since such sectors mostly need raw materials and intermediate inputs for performing their activities. This group of variables is opposed to a profile of urban centre where tertiary activities, especially the financial sector, retail, as well as population, density, and regional GDP are closer to manufactured goods traffic. The clustering (Figure 4) confirms that such regions are large coastal capital cities (Oslo, Stockholm, Copenhagen, Hamburg, London, and Lisbon), mostly located in North Europe (first cluster). Except for Helsinki, Gdansk, Piraeus, and Bilbao, regions belonging to the second cluster tend to locate close to Europe's core economic areas, i.e. the European megalopolis from London to Milano. There is thus a relatively strong influence of continental location on the nature and level of port-region linkages in Europe. The fact that combustibles, traffic size, international and import traffics also participate to this trend indicate that those larger and richer regions are mostly consumer markets best connected to global flows. This trend is very important as it marks a very logical functional contrast between traditional regions and advanced regions. The cluster of traditional regions is, indeed, generally located at the periphery of Europe (e.g. Greece, Atlantic, Scandinavia) despite a few exceptions such as East Flanders, North Brabant, and Luneburg.

The second trend (PC2) is mostly an opposition between large, international traffic of combustibles and regions specialized in minerals and metals, with a tendency to be also richer and more densely populated on average. This can be interpreted as an opposition between a profile of Maritime Industrial Development Area (MIDA) specialized in the industrial sector while handling petro-chemical traffics (Vigarié, 1981) and a profile of urban region specialized in solid bulks and general cargoes. Other trends show an opposition between a profile of steelworks region (PC3) based on metals traffic and the industrial sector and a profile of deprived region where unemployment is higher than average. On the map, clusters show a rather strong spatial pattern. Deprived regions (third cluster) are mostly in Southern Europe (southern Italy, Andalucia) with the exception of Mecklenburg-Vorpommern (Germany); they have in common to have been the focus of growth pole strategies in the 1970s based on heavy industries as well as container hub strategies in the 1990s (e.g. Algeciras, Cagliari, Gioia Tauro, Taranto), but such projects have not succeeded in creating more employment and regional balance, in a context of oil crisis and due to the limited local economic impacts of container transhipment. This cluster is built in opposition to GDP and the industrial sector, which suggests lower economic wealth and weaker industrial base. Another group of regions (fifth cluster) is better defined by specialized traffics serving local industries specialized in metals and manufactured goods, such as Antwerp, Zeebrugge, Bremen, and Valencia, with more international openness and stronger socio-economic backgrounds. Lastly, the most geographically spread category (sixth cluster) is composed of port regions specialized in combustibles with a high importance of the immediate hinterland (friction). They have in common to be remotely located from Europe's core economic regions and/or to face industrial reconversion, such as Dunkirk in the Nord-Pas-de-Calais region as well as most United Kingdom regions. Their specialization is defined in the cluster in opposition to the first cluster (GDP, finance, manufactured goods) thereby reinforcing the idea of relatively deprived regions where heavy industries and lower valued goods dominate.

[Insert Figure 4 about here]

4.3 Japan

The main trend (PC1) opposes large cities to traditional industrial regions. Large traffics and traffics of manufactured goods are well represented against combustibles and friction. As seen in Figure 5 (first and second clusters), it corresponds to a handful of large urban regions (i.e. the Japanese megalopolis from Tokyo to Fukuoka) producing and consuming many value-added good. Tokyo stands as the only multifunctional centre but it has in common with the second class important features such as being a large tertiary centre and a large port simultaneously. This recalls the pattern of hinterlands in Asia (Figure 1) where there is a good adequacy between economic concentrations and traffic concentrations for the aforementioned reasons. Such large urban regions handle about half of domestic freight cargo through interregional flows. Although they are less represented on the first component (PC1), international traffic and traffic diversity are positively correlated with such trends, as well as retail, thus supporting further the profile of dynamic and global urban regions. On the other hand, traditional regions are characterized by a coincidence between the agricultural, industry, and construction sectors and traffics such as combustibles, agricultural goods, and minerals. This opposition recalls the one found in Europe and provides similar spatial patterns on the map, with advanced urban regions being core economic regions and traditional regions being more peripheral (fourth cluster).

The second component opposes a profile of industrial region handling combustibles and international traffic with a profile of agricultural and deprived region (unemployment) mostly handling minerals. Thus, the first trend suggests the existence of strong local industry linkages mostly through importing raw materials for processing plants, again recalling the trend on Europe based on the concept of MIDA. Such regions have more favourable socio-economic environments than in the opposed trend as seen with the positive sign for regional GDP; they serve as strong industrial areas for domestic supply chains, such as Mie, Toyama, Ishikawa, Aichi, Fukushima, Shizuoka, Fukui, and Ibaraki. The opposed trend comprises two peripheral regions (Hokkaido and Okinawa) and are not characterized by specific economic functions except for public services. Other trends point at another opposition between deprived regions handling large volumes of combustibles and more advanced regions handling mostly raw materials (minerals, metals) while being specialized in the industrial sector. Those advanced regions benefit from their inclusion in the megalopolis, they are specialized port regions complementing the functions of nearby tertiary centres through a spatial division of activities (i.e. backward linkages) along the main urban corridor of the country.

[Insert Figure 5 about here]

4.4 United States

The case of the United States provides a very clear opposing trend (PC1) between urban tertiary centres handling most valued goods and traditional regions handling mostly raw materials, as seen in the two former cases. One common trend with Europe is that, unlike for Japan, combustibles traffic is grouped with manufactured goods. In fact on the map (Figure 6), it shows the prominence of East coast port regions together with Texas and California, which concentrate higher-order activities, population, and largest traffics. Massachusetts, Rhode Island, and Connecticut belong to a separate cluster (second) where combustibles are better represented than in the first class hosting major metropolises. They are functionally and spatially opposed to port regions located for their majority in the interior and characterized by agricultural traffics (fourth cluster) and to Midwest regions specialized in the industrial sector and minerals traffics. Such traditional port regions have also in common certain social weaknesses due to difficult reconversion (e.g. rustbelt) and declining population. This echoes a relatively well-known regional geography of the United States where port traffics simply reflect the dominance of certain local industries. Other port regions are those specialized in specific industries and traffics and are often geographically confined to certain areas, such as agricultural and chemicals in the Northwest and at the mouth of the Mississippi (e.g. Washington, Louisiana), manufactured goods and metals in Georgia and South Carolina. Those two latter regions have a very diversified industrial background.

[Insert Figure 6 about here]

5. Conclusion

This paper has provided a novel analysis of the interplay between the local socio-economic conditions of areas surrounding ports and the nature and structure of port traffics, based on a dataset of 21 indicators covering 189 so-called port regions in Europe, Japan, and the United States. Main results can be summarized as follows. First, the statistical relationships between socio-economic variables and port traffic variables are meaningful because they underline rather logical sector-specific links whereby certain traffics have noticeable affinities with specific regional characteristics. Thus, despite the probable mismatch between administrative regions and the true extent of port hinterlands, ports traffics are very sensible to the nature of the local economy in which they are handled. Second, the three studied geographical areas, despite wide differences in historical legacies, spatial and trade patterns, share noticeable similarities in the nature of port-region linkages. Economically and demographically larger, richer regions where the tertiary sector dominates often concentrate larger, more diversified traffic volumes as well as higher valued goods such as containers and consumer products, as opposed with agricultural and industrial regions, which are more specialized in bulk traffics in relation with their dominant activity. There are, of course, local specificities across the three regions as such trends are more linear in Japan due to the better overlap between port hierarchy and urban hierarchy and the simple fact that Japan is an island country thus limiting transit flows. The industrial sector also does not have the same influence on port traffic specialization depending on the context but overall, there is a striking invariance in the results beyond local specificities. The typology of port regions obtained through hierarchical clustering also confirmed a very logical distribution of different types of port-regions linkages, often showing a contrast between the core (e.g. megalopolises) and the periphery within the country or continent. The outcomes of the research allow to confirm that port activities are not disconnected from their local economies, so that further research is needed in order to push further the analysis of port-region linkages, perhaps by zooming in a more disaggregated way on traffics and employment sectors, thus allowing to better discuss the implications of strong port-region linkages on current and future local economic development opportunities and strategies.

Possible improvements may be obtained by more in-depth reflection about the correspondence between administrative units where socio-economic data is available and hinterland patterns, traffic catchment / generation areas around ports. Attributing different administrative levels to ports according to the volume and nature of their traffics could be one interesting direction to consider, with smaller and more distance-constrained ports being bound to lower administrative levels (e.g. NUTS-3 region in Europe, county in the United States, sub-prefectures and districts in Japan) or city levels (e.g. Functional Urban Areas or Large Urban Zones in Europe, cities and wards in Japan), while larger ports could be attributed an intermediate level (NUTS-2, state, prefecture) and largest ports extending across two or more regions, such as Le Havre and Rouen (France) being counted as ports of the whole Seine axis including the two NUTS-2 units of Greater Paris region and Upper Normandy or even the NUTS-1 level comprising Ile-de-France and Bassin Parisien. Perhaps, such exercise would prove even more successful by considering the spatial layout of the transport network. In any case the correlation between port traffics and regional specialization shall be closer to reality, i.e. without amputating too much port hinterlands while remaining within reasonable geographical limits. Another possible research direction is the extension of the analysis to other geographical areas where data is potentially available, in the developed (e.g. Australia, New Zealand, Mexico Canada, South Korea, Hong Kong, Singapore) and developing (e.g. India, Russia, Brazil, Turkey, China) worlds. This effort would possibly confirm the existence of invariants in port-region linkages and balance the results obtained here on developed countries only. Other indicators could be integrated in the analysis, such as passenger flows (ferry, cruise), flows by other transport modes such as air flows to study their combination with port traffics (see Ducruet et al., 2011), connectivity indicators in maritime and land-based networks (see Chapelon, 2006; Thill and Lim, 2010), but also other regional indicators such as about innovation, environment, and wages depending on their large-scale availability. Lastly, it is fundamental to consider dynamics in both traffics and socio-economic conditions of port regions, in order to verify possible convergence between respective diversification and specialization processes and, perhaps, better identify to what extent changes in port traffic structure not only illustrates but also influences local socio-economic development.

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Port	Total port traffic *		Share of the local administrative unit in total port traffic *		Container traffic **	
	Volume (tons)	Value (Euros)	Volume (%)	Value (%)	Volume (tons)	Share in total port traffic (%)
Rouen	8,942,804	10,525,770	69.0	13.5	1,136,000	5.2
Le Havre	8,305,550	29,213,899	22.8	13.4	17,685,000	25.0
Marseille	7,019,774	7,986,530	64.5	22.3	7,292,000	7.8
Dunkerque	3,937,047	2,294,024	79.8	41.5	1,559,000	3.2
Nantes-St. Nazaire	2,631,685	959,309	73.5	54.1	1,169,000	3.4
Languedoc-Roussillon (a)	2,041,343	534,717	76.5	73.2	61,000	1.6
Bordeaux	1,292,146	392,860	95.3	78.2	444,000	5.2
Bretagne (a)	1,242,471	388,765	99.5	97.9	234,000	9.6
La Rochelle	1,074,273	155,471	99.6	96.8	0	0.0
Dieppe	326,985	104,036	78.7	37.3	38,000	3.8
Boulogne	42,879	27,760	57.4	26.9	0	0.0

Table 1: Weight and share of coastal regions in French ports' traffics in 2005

Sources : calculated based on * Guerrero (2010) and ** Eurostat

(a) reference is the Région instead of Département

N.B. data accounts for extra-EU maritime flows excluding oil products

Type of indicator	Code	Specialization	Code	General characteristics
Port traffic	T_COMBUS	*Combustibles (coal, oil, gas)	T_SIZE	*Traffic size
	T_CHEMI	*Chemical products & fertilizers	T_IMPOR	*Import/inbound traffic
	T_METAL	*Metal products (iron & steel, scrap)	T_INTER	*International traffic
	T_AGRIC	*Agricultural, forestry products & live animals	T_DIVER	*Commodity diversity
	T_MINER	*Minerals & construction materials (ores, sand, gravel)	T_FRICT	***Spatial friction
	T_MANUF	*Manufactured goods (containers, vehicles, food products)		
Socio-economic	R_AGRIC	**Employment in agriculture and fisheries	R_POPUL	*Demographic size
	R_CONST	**Employment in construction	R_DENSI	*Population density
	R_INDUS	**Employment in mining & manufacturing	R_UNEMP	**Unemployment
	R_RETAI	**Employment in retail, hotel, & transport	R_RGDP	**GDP per capita
	R_FINAN	**Employment in finance & real estate		
	R_PUBLI	**Employment in public services		

Table 2: List of traffic and regional indicators

* index based on national/continental average ** index based on national average *** other method

	Area	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalues	Europe	4.086	2.623	2.264	1.784	1.299	1.191
	Japan	6.666	3.752	2.390	2.108	1.358	0.954
	USA	4.738	2.919	2.661	2.094	1.904	1.485
Cumulated variance	Europe	19.456	31.945	42.725	51.219	57.403	63.072
	Japan	31.742	49.610	60.992	71.032	77.500	82.040
	USA	22.560	36.460	49.133	59.103	68.168	75.238

Table 3: Main results of the Principal Component Analysis (PCA)

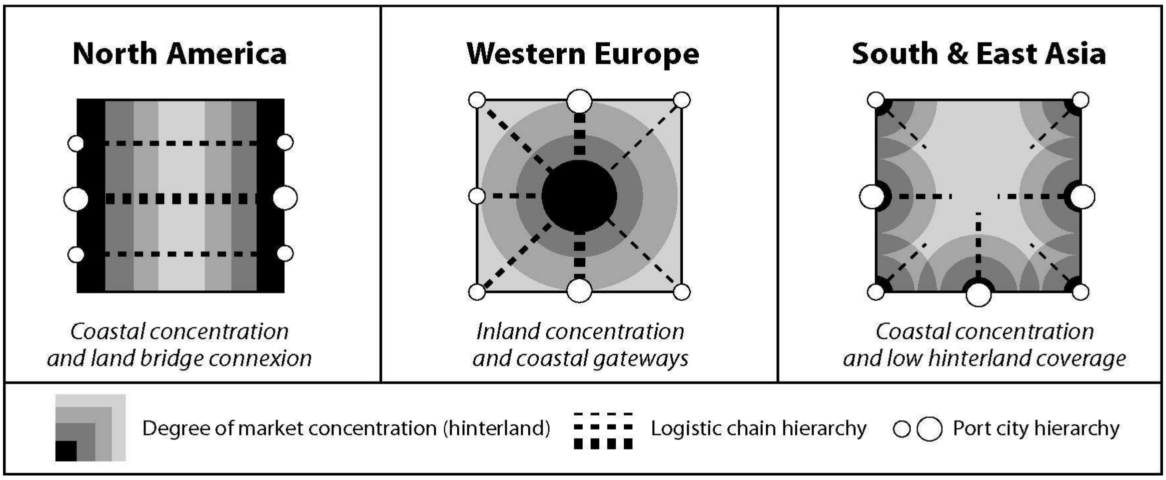

Figure 1: Hinterland patterns of some large regions

Source: Lee et al. (2008)

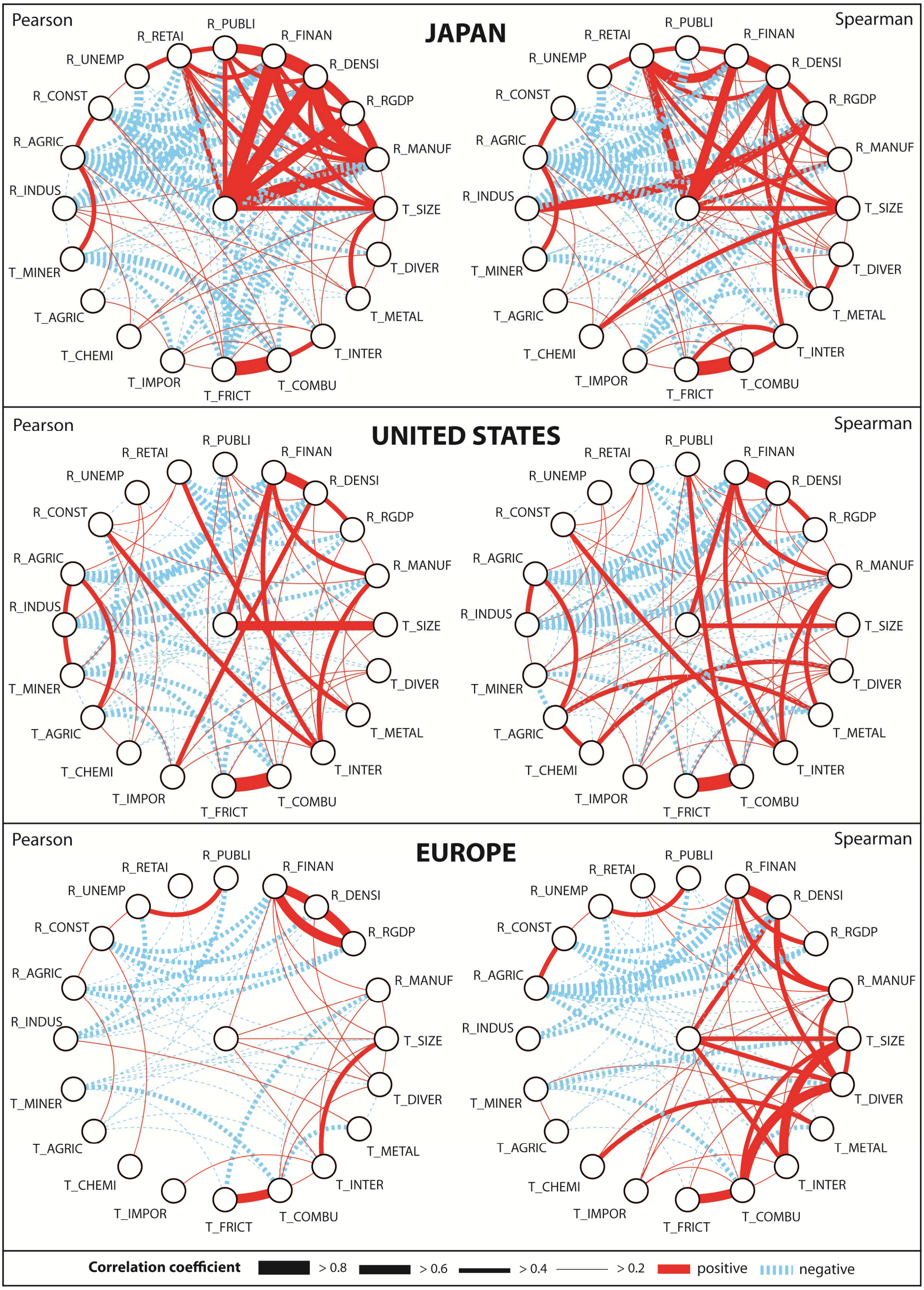

Figure 2: Correlations among all variables in 2008 by geographic area

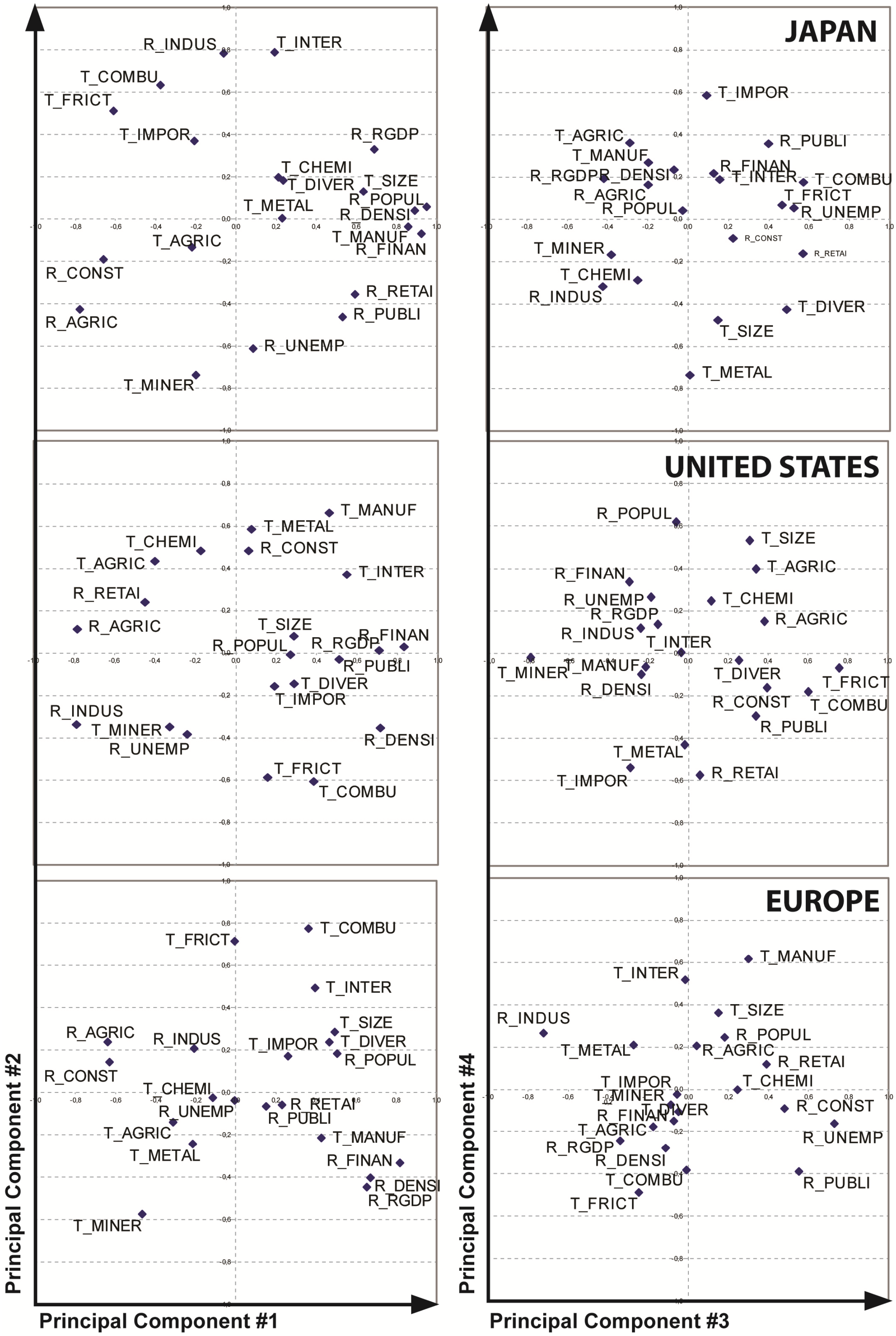

Figure 3: Position of variables on the fourth principal components

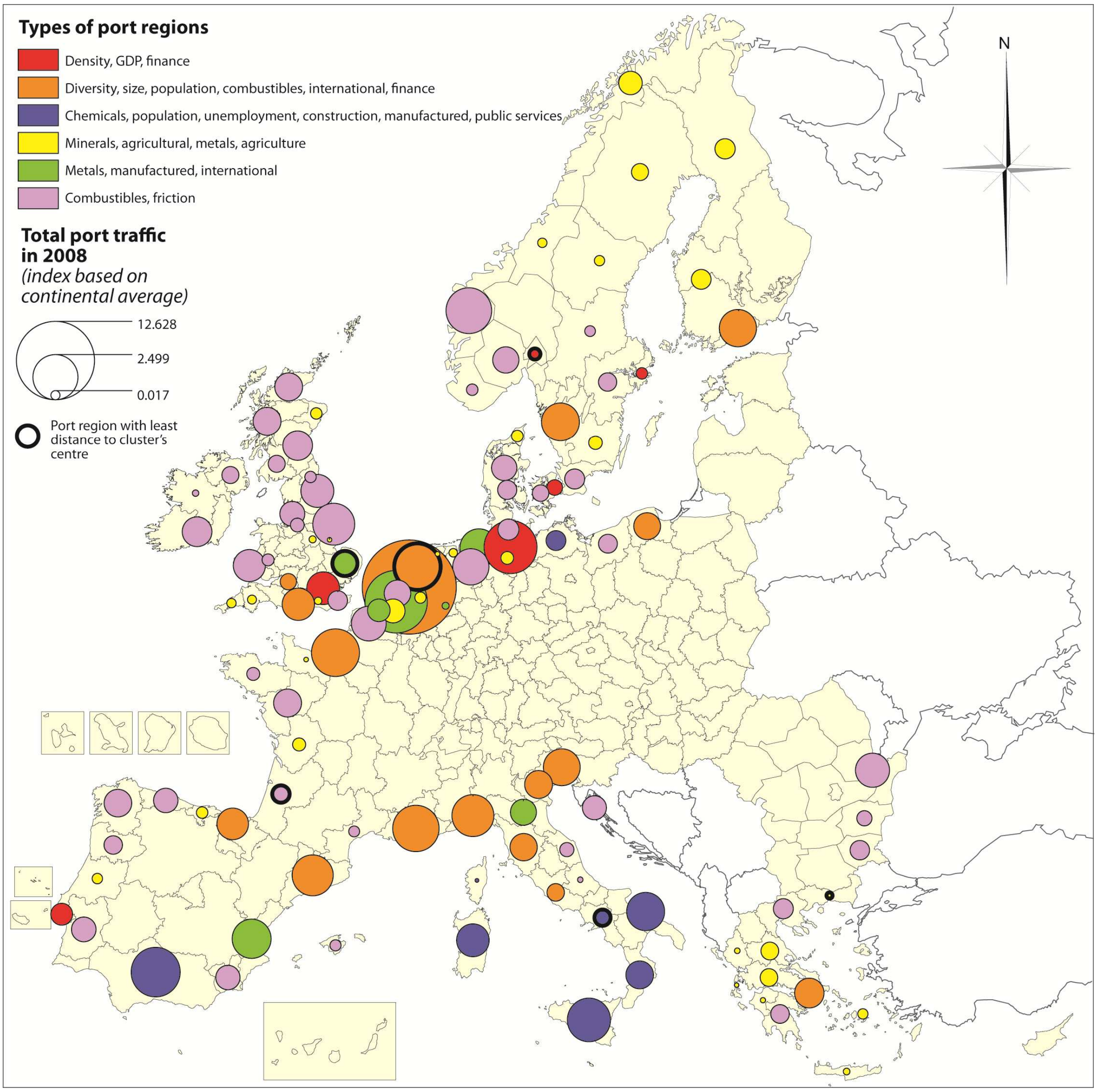

Figure 4: Typology of European port regions

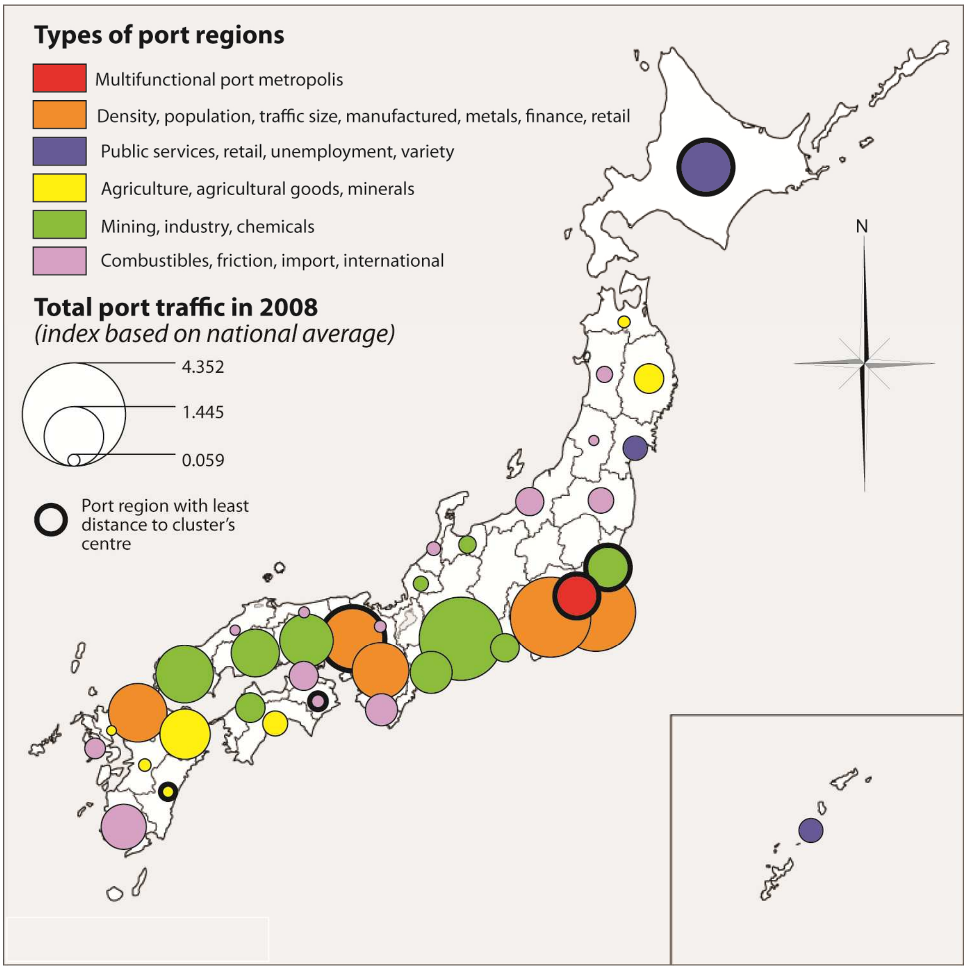

Figure 5: Typology of Japanese port regions

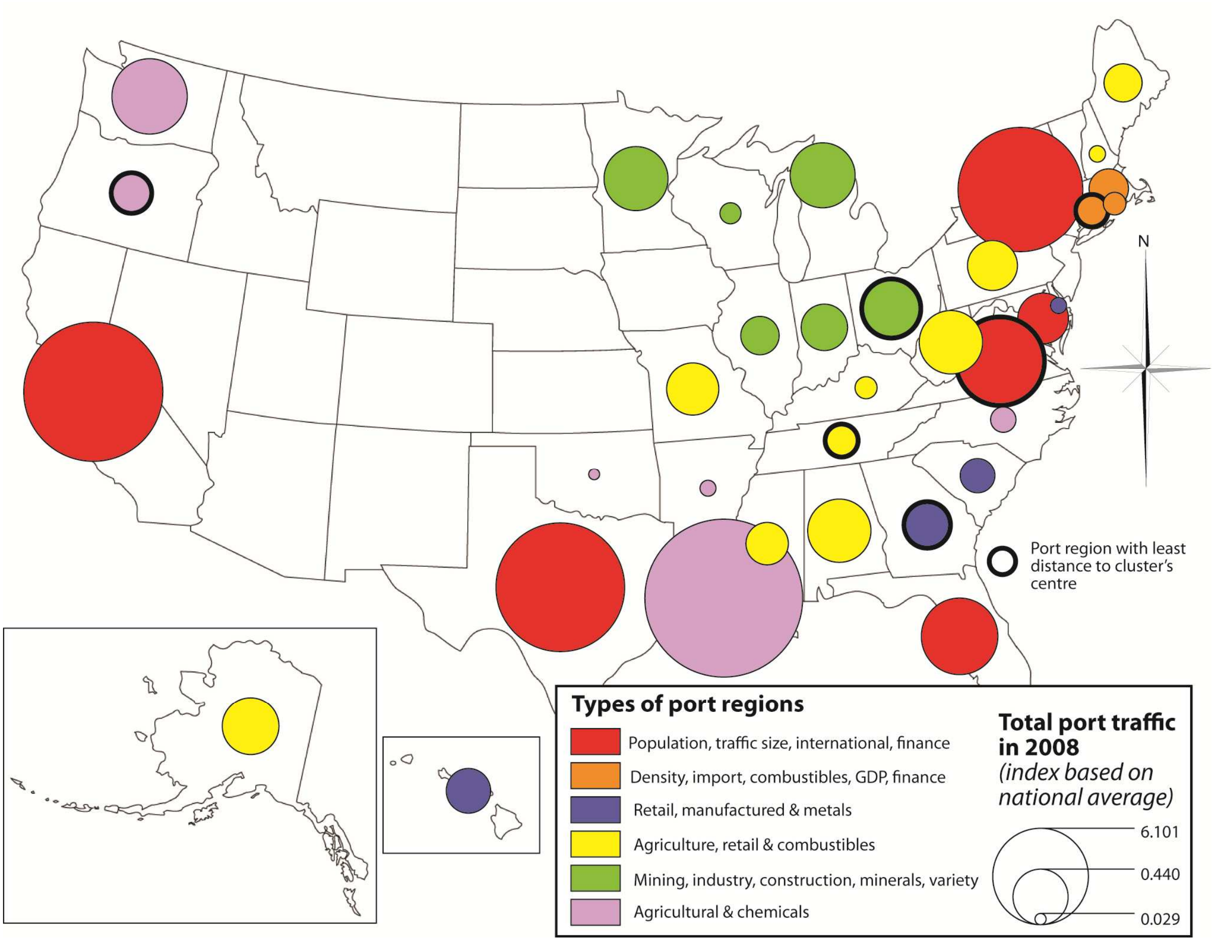

Figure 6: Typology of American port regions