The mutual specialization of port regions connected by multiple commodity flows in a maritime network

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Throughout port and maritime studies, the link between flows and the socio-economic characteristics of localities has been investigated mostly qualitatively. While systematic international quantitative investigations remain scarce and dispersed, their reliance upon port tonnage statistics tends to ignore maritime linkages. Conversely, maritime network studies remain abstract, where ports are considered only as nodes in a graph. What is the influence of the local economy on the situation in – and specialisation of – maritime networks? Are there significant interrelations between types of maritime flows and types of local economies? Such an approach shall first discuss the wider scientific literature about transport and regional development, with a particular focus on previous quantitative studies. Secondly, this chapter provides an analysis of the Pacific Rim area based on the comparison of vessel movement data and regional socio-economic data collected at the level of subnational entities or port regions. The fact that populations and markets are concentrated on the coastlines of North America, Asia, and Oceania (Lee et al., 2008) motivated the search for spatial and functional interdependencies between traffic and local economic structure. In addition, the Asian-Pacific Rim "had become the indisputed main generator of containers" in the world (Rimmer, 2014, p. 91) and a major concentration of multinational industrial and logistics corporations.

Regions, material flows, and maritime networks

A great variety of research throughout the academic literature has addressed the link between regional development and material flows. Reference to such flows is often implicit, however, as for instance in urban economics and location theory (Fujita et al., 1999; McCann and Shefer, 2004; Beyers and Fowler, 2012), in regional development theory (Dawkins, 2003), and in studies of economic growth and globalisation (Scott and Storper, 2003), and of commodity chains, global production networks, and world cities (Leslie and Reimer, 1999; Dicken, 2001; Derudder and Witlox, 2010). Empirical investigations are often qualitative case studies of particular places and contexts. Quantitative analyses are done mostly at the national level (Harrigan, 2004), while those done at the regional (sub-national) level mainly focus on mobility and communication flows, without always measuring their interdependence with local socio-economic development. One example is evolutionary economic geography, which analyses regional branching and industry relatedness by looking at flows of labour, firms, and knowledge (Boschma and Frenken, 2011a). More specialised studies of (freight) traffic flows do exist, but they often ignore the local context, such as studies of transport networks addressing issues of accessibility and connectivity (Ducruet and Lugo, 2013).

The few existing empirical studies of material flows in relation to their local environment come from very diverse schools of thought and methods, of which urban ecology and regional science. As reviewed by Ducruet and Itoh (2015), regional scientists focused on the impact of transport infrastructure on the intensity of trading flows and on the location of economic activities, with applications to ports focusing on infrastructure quantity, quality, its influence on trade, economic development, manufacturing costs, private investment, capital stock, employment, etc. Other approaches included measuring the local determinants of regional exports in terms of transport costs and sea access, the influence of gross regional product on airline accessibility and urban centrality of cities, and the distribution of supply chain networks in relation to urban hierarchy (see Guerrero and Proulhac, 2014).

The case of ports and port regions offers mixed evidence, and local socio-economic development in relation to ports has not been fully studied from a maritime network perspective. On the one hand, certain studies confirmed the weakening spatial fix of port traffic as a combined effect of shipping line concentration and service rationalisation, new port development outside urban cores to avoid congestion, with a growing gap between white-collar urban regions and blue-collar port regions in terms of economic structure, wage level, economic productivity, and presence of advanced producer services. But despite their sometimes global focus, such empirical studies mostly focused on Western cases, such as the United States, Canada, and Europe (Ducruet et al., 2010) or richer countries (Ducruet, 2009; Ducruet et al., 2015). Yet, large European port gateways may expand their hinterlands further inland but at the same time maintain strong local linkages through heavy industrial complexes (Merk et al., 2013; Botasso et al., 2013; Guerrero, 2014). Nevertheless, the majority of studies contradicting the erosion of port-region linkages are of Asian essence (see Fujita and Mori, 1996 for a general discussion). In Japan, port investment had significantly positive effects on GDP and private capital (Kawakami and Doi, 2004) as did port efficiency on shipping cost and GDP growth (Doi et al., 2001). In China, industrial productivity had a positive influence on port traffic growth (Cheung and Yip, 2011), while port-related added value had a positive impact on regional economic growth (Deng et al., 2013), sometimes depending on the location, stage of economic development, and land transport density of the different provinces (Song and van Geenhuizen, 2014). Despite a diversity of methods and outcomes, these studies remain bound to single-country datasets and neglected the importance of maritime linkages between (subnational) port regions (see a complementary discussion in Chapter 20 by Ducruet et al. on port cities).

The network analysis of maritime flows has progressed rapidly in the last decade or so (see Chapter 1 for an overview), but little has been done about their local socio-economic embedding. In terms of commodity specialisation, Ducruet (2013) demonstrated the strong influence of commodity diversity on port centrality and maritime network structure, but without discussing the role of industrial linkages. Crossing port throughput and regional data across both developed and developing countries could show that core economic regions, which are richer and more densely populated, concentrate international and valued traffic (general cargo, containers), while peripheral regions, which specialise in the primary sector, concentrate more bulky flows (Ducruet and Itoh, 2015). Such an analysis was inspired by recent works on place- and path-dependency in economic geography (Boschma and Frenken, 2011a, 2011b; Neffke et al., 2011) as well as previous discussions on commodity specialisation and regional specialisation (Tabuchi and Thisse, 2002).

A network methodology can push further our understanding of port-region linkages in several ways. In line with previous research based on port throughput data, it can elucidate whether maritime traffic specialisation is related with economic sector specialisation, if certain socio-economic characteristics influence nodes' position in the network, and if similar types of port regions strongly connect each other, and through which type of commodity flow. To some extent, this chapter searches for technological coherence (Boschma and Frenken, 2011b) between flows and spaces.

Mutual specialisation effects across Pacific Rim port regions

Data and methodology

One first step has been to obtain vessel movement data from one issue of the *Lloyd's Shipping Index* published in 2008, which covered 88.8% of the world fleet capacity measured in deadweight tonnage according to UNCTAD (2008). The 23,675 recorded vessels were categorized into five main types for the sake of simplicity (general cargo, container, liquid bulk, solid bulk, and passenger/vehicle), measured in deadweight tons (DWT). A total of 518 ports were recorded in 13 countries of the Asia-Pacific region, for which socio-economic data at the regional (subnational) level was available (Table 16.1), resulting in 124 port regions. Regional data was collected for the year 2009 except for China and Taiwan (2010) and selected according to potential effects and links with vessel traffics (Table 16.2). The local economy is described via seven variables: employment in three main economic sectors (primary, secondary, and tertiary), demographic weight (or population share), population density, gross regional product (GRP), and unemployment rate. Regional variables were transformed into location quotients based on national average to avoid possible biases caused by structural differences among countries in terms of economic structure and statistical definitions.

Five traffic categories cover the whole spectrum of port and maritime activities, alongside the shares of inbound and domestic traffic and the share of regional traffic in the national total. Traffic categories were weighted (Charlier, 1994) in order to better reflect their potential cargo value and employment generation power at the docks and terminals. The variables (indicators) of (port) traffic categories for each region indicate the share in total regional traffic except for the share of regional traffic in (total) national traffic. Lastly, this empirical analysis includes network centrality variables (indicators) calculated at the global level of the worldwide graph: degree centrality (or number of links) and hub function (or position of networks), for discussing interdependencies between the socio-economic profile of the port region and its connectivity in the maritime network. The hub function of the port region is the inverse value of its clustering coefficient[1]: higher values underline a strong bridge or hub position towards immediate neighbours in the graph.

The study sample represents 49.9 percent of total world traffic, with a slightly higher share for containers (60.5 percent) and solid bulk (67.4 percent) than passengers and vehicles (47.1 percent), general cargo (36.9 percent), and liquid bulk (32.9 percent). This traffic structure reflects the intensity of container flows across the Asia-Pacific, such as between China and the United States, and the growing trade of raw materials such as cement, coal, metals, and minerals from Australia. The selected port regions constitute subnational administrative entities in each country, such as Chinese provinces and American states, where one or more ports operate. Such a level of analysis allows mixing regional and port traffic variables in a common database and takes into account the local or captive hinterland of ports, where most clients are located and where port-related activities concentrate, such as in the port city or port cluster. It is unfortunately impossible to distinguish local trade from transit trade in maritime statistics as the same region may be the origin/destination of flows but also a gate to access inland core regions beyond local needs (Itoh, 2013). For instance, inland rural regions may ship their exports through a port situated in an urban region acting as the main gateway (Löfgren and Robinson, 1999), and vice-versa.

A simple, linear regression between total vessel traffic and total port tonnage[2] showed a significant relationship with a determination coefficient of 0.49 and 0.57 for non-weighted and weighted figures, respectively. The fitness of weighted figures is slightly better than for non-weighted figures due to the higher efficiency of shipping networks and their high load factors for valued cargoes such as containers. Therefore, this empirical analysis adopted weighted figures as indicators for discussion of the relationship with regional activities. Differences in data sources such as time coverage and measurement unit may lower the relationship as well as the inclusion of landward (hinterland) flows in port tonnage.

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[1] Percentage of actual closed triplets (or triangles) in the maximum possible number of closed triplets (or triangles) for each port and its neighbours.

[2] Port tonnage statistics in metric tons were obtained from various international and national organisations for the year 2009.

[Table 16.1 here]
[Table 16.2 here]

Preliminary results

A principal components analysis (PCA) was applied to the 17 port and regional variables (see also Table 16.2), from which Figure 16.1 presents the two first main factors (see also Appendix 16.1 for more detailed results). Overall, the results point to a very significant relationship between traffic specialisation and regional specialisation. As such, regions specialised in primary activities tend to have a higher share of solid bulk, standing apart from other variables (the second quadrant in the figure). An opposite trend is that regions specialised in services (tertiary sector) while being richer and more densely populated concentrate container flows (the fourth quadrant in the figure). This opposition already underlined by Ducruet and Itoh (2015) based on port throughput statistics in a global perspective, confirms that (maritime) traffic is not randomly distributed across space and therefore reflects the dominant character of the place where it is handled, despite the impossibility of distinguishing transit flows (transhipment) from trade flows (hinterland) in total shipping activity, and correcting for possible spatial and functional mismatches between administrative regions and port hinterlands.

In addition, on the first factor, degree centrality is clearly if onlypartly determined by demographic concentration and GRP per capita and high traffic share, which corroborates the aforementioned works on airline networks and cities. Regions specialised in the secondary (industrial) sector are likely to act as hubs in the maritime network, i.e. to be distribution platforms of hub-and-spokes configurations with an average hub function. When considering the second factor alone, negative scores underline some affinity between the tertiary sector, liquid bulk, domestic, and inbound traffic, as service or urban regions are important consumption centres for fuels (Graham, 1997; Decker et al., 2000). The remaining variables have less significance along the two first factors. However, results show that passenger and vehicle traffic is closer to the tertiary sector and to population share and population density to a lesser extent for the third factor, while general cargo traffic is closer to the industrial (secondary) sector, and density to GRP for the fourth factor.

[Figure 16.1 here]

Eight coherent groups of port regions were obtained from a non-hierarchical clustering based on the PCA (see Appendix 16.2[3] for an overview). The first cluster (*industrial centre*) is the largest by the number of port regions and its share in total vessel traffic (36.8 percent). It is also the only cluster with a positive, pronounced

[3] This table shows the weighted impact values of each indicator calculated by cluster' centres and components' scores from PCA in each cluster.

specialisation in the industrial sector rather than services. Yet, its traffic profile is only slightly specialised in solid bulk, containers, outbound, international, and degree centrality, but a negative score for hub function. The second cluster (*value-added city-hub*), with only 10 regions but 18 percent of the sample's traffic, is highly specialised in containers, general cargo, and international outbound traffic, with important degree centrality, traffic share, and hub function. Interestingly, such a profile goes along with the concentration of population, density, but also unemployment and a balanced role of the tertiary and industrial sectors. The third cluster (*agri-bulk hub*), with only seven regions, still captures 17.4 percent of total traffic as it shares the same profile than the former as a hub concentrating traffic and population, but with a specialisation in primary activities and solid bulk and traffic share, and a lower density. The second and third clusters only have higher degree centrality and hub function both with high traffic share and population share, but a higher unemployment rate than the national average, probably caused by excessive immigration inflows. The fourth cluster (*energy centre*), with 25 regions, accounts for only 10.3 percent of total traffic. Such regions are smaller in size (traffic, demography) and are mostly domestic import regions for liquid bulk to fuel primary and tertiary activities.

The fifth cluster is a special case with only three regions and less than 1 percent traffic, mostly defined by passengers and vehicles, tertiary activities and to a lesser extent some primary activities as well as containers and international outbound. The sixth cluster (*construction centre*), with 19 regions, has only a small traffic share (7.5 percent), as these regions handle small traffic volumes of mostly solid bulk and inbound flows, but within a dense and tertiary environment, relatively poorer than average and more peripheral in the network. The combination of solid bulk and tertiary sector may relate to the importance of construction activities. The seventh cluster (*metropolitan gateway*) is similar to the second by its specialisation in containers, general cargo, density, and degree centrality, but its profile is much more influenced by GDP (a much richer region), tertiary activities, and domestic outbound traffic, with less unemployment, less developed hub functions, and a higher concentration of traffic and lower population within the host countries. Because port regions in this cluster have high degree centrality (or many links) but a limited hub function (or in a relatively secondary position in the maritime network), their negative score for the industry sector and highly positive score for bulky traffic underline needless supply chain advantages. Finally, the last cluster (*periphery*), with 13 regions, has a very low traffic share (1.1 percent) and specialises in general cargo and the primary sector. The combination of low population density, low GDP, and lower degree centrality and lower hub function suggests a region with logistical and socio-economic difficulties. In contrast to the second and third clusters, or hub clusters, periphery regions are far away from maritime trunk lines.

Port-region specialisation and the maritime network

The share and dominant commodity type of vessel traffic among the clusters are presented in Figure 16.2. Each line corresponds to the sum of (weighted) vessel flows between each cluster and others, while the specialisation of each link (crossing) is highlighted by grayscale based on a coefficient calculated by rows and columns. For instance, 25.1 percent of flows of industrial centres connect value-added city-hubs, and this link is mostly made of containers, whereas 40.8 percent of flows of value-added city-hubs connect industrial centres, mostly based on liquid bulks. In other words, this figure shows the degree of vessel traffic dependences for each link between regions of each cluster. The specialisation coefficient differs on the same link depending on which cluster is the reference for the total. Unsurprisingly, the two clusters specialised in container traffic connect each other and other clusters mostly through container flows, while container flows do not occur on any pair of other clusters. They also have a high degree centrality (but middle and negative hub function) and density, and tertiary region, or urbanized (less industrialised) profile. Dependence and specialisation linkages can vary depending on the chosen perspective. All clusters are linked to agri-bulk hubs with varying degrees of dependence but dominantly based on solid bulks, albeit conversely, while agri-bulk hubs depend for 60 percent of their traffic upon industrial centres, again based on solid bulks. The rest of their flows with other clusters are more specialised in other commodities. Thus, there is a spatial division of economic activities among port regions that is well apparent when looking at the nature of maritime flows connecting them. Although this analysis does not take into account the flows between port regions and inland regions through land-based transport, it is already able to capture a noticeable part (if not the backbone) of the value chains for this part of the Pacific Rim area.

[Figure 16.2 here]

Lastly, the analysis proposes a simplification of the graph to highlight the dominant structure of the maritime network (Figure 16.3), based on the “nodal region” methodology proposed by Nystuen and Dacey (1961). Based on weighted vessel traffic in the multigraph (or multiplex graph), only the largest flow (or vessel traffic) link of each region to another region has been kept, with its commodity type and shipping direction, thus making a weighted and directed tree graph while splitting the network into three connected components, or strings of links. The largest component has a line or corridor structure centralised on a few large hubs, such as Gyeongnam (Korea), Kanagawa (Japan), California, Shanghai, Beijing/Tianjin, and Western Australia. All these hubs have a different nature, so one may assume the existence of a polycentric, multifunctional system. Two other smaller components are made of Queensland and New South Wales centralising mainly Japanese regions by means of solid bulk and general cargo flows on the one hand, and of Maharashtra (India) and Selangor (Malaysia), connecting mainly South Asian regions through container and general cargo flows.

The largest component is geographically diverse in terms of port region clusters and nodal commodity flows. It conveys major flows from two distribution or consolidation sources (Gyeongnam and Western Australia) towards one sink, composed of Chinese port regions (Shanghai and Beijing/Tianjin metropolitan gateways) alongside a number of other secondary sources in terms of traffic volume. Even though this analysis only focuses on the Pacific Rim area, California stands out as the largest traffic region to which multiple commodity flows of various natures converge, mostly containers. California is also the gateway for inland freight movements in North America. While the right-hand side of the figure (south, mainly Australia) is made of bulk chains, the left-hand side (mainly Japan and South Korea) is composed of light industry chains. Although directionality only applies to vessel movements, not trade import or export, it helps in understanding how major production regions of raw materials (e.g. grain, coal, minerals, and ores) are focal nodes for redistribution towards consumption regions and intermediate regions between them.

[Figure 16.3 here]

One very important outcome of this analysis is that the network centrality of port regions is much influenced by the local socio-economic environment (see also Appendix 16.2). For instance, the cluster of agri-bulk hubs is the only case where regions can have low GDP, high degree centrality, and lower population density, due to the specific case of (solid) bulk traffic that employs relatively lower-skilled workforce and less advanced technologies for production and shipment, and also fewer industries or services, with less connectivity function for industries. Most of the time, strong hub functions and high degree centrality (i.e. many maritime links) go along with a higher GDP than the national average. Although this may be in some way counterintuitive due to the limited developmental impact of transhipment hub ports, it still validates a number of ideas about the positive externalities provided by (dynamic) cities to ports (Hall and Jacobs, 2012).

In the maritime network, the so-called industrial centres as well as the agri-bulk hubs are essential for feeding the more urbanised port regions concentrating populations and services along the main trunk line. Important subsystems also appear, such as among Chinese provinces in the northern part of the country (Shanghai, Beijing, Shandong, Liaoning, Zhejiang, Jiangsu), while Guangdong, the factory of the world, is more strongly connected with California, the main gateway to China's largest customer of finished products. International and domestic logistics intermingle due to complex distribution circuits such as coal shipping, notably since China shifted from being the world's main exporter to being its main importer, using coastal shipping internally (Wang and Ducruet, 2014). Still, the largest regional economies are much connected with each other along the trunk line, proving the influence of hierarchy and market size on network configuration. As a complement, most of the secondary linkages are dominantly in proximity, i.e. within specific sub-regions of the Pacific Rim: Yellow Sea (Korea-China), Japan (coastal shipping), China (domestic river transport), East Sea (Korea-Japan-Russia), etc. The role of multifunctional distribution platforms such as Busan (Gyeongnam region), is of course one main explanation, beyond shortsea linkages. Although Hong Kong and Singapore, two dominant East Asian hubs, are excluded from this study due to the absence of district-level socio-economic data, such evidence well depicts the emergence of Asian hubs in a context of intensifying trans-Pacific trade (Robinson, 1998).

Conclusion

The analysis of the socio-economic determinants of port and maritime traffic across the Pacific Rim region is fruitful in many ways. First, it confirms that the intensity, specialisation, and spatial distribution of maritime flows are far from being random or disconnected from the local environment where such flows are handled. Such evidence confirms previous empirical investigation based on worldwide port traffic statistics (Ducruet and Itoh, 2015), despite the fact that land-based (or hinterland) flows are not included per se in vessel movement data. As such, tertiary regions tend to concentrate container flows, and regions specialised in the primary sector concentrate solid bulk traffic. One particularity of the Asia-Pacific area is the higher centrality of industrial regions in the maritime network, due to the export-led profile of many Asian economies for manufacturing, as part of a global horizontal division of supply chains, especially in Northeast Asia, including Taiwan. Another peculiarity is the hub function of certain regions specialised in raw (solid) materials traffic as they distribute natural resources worldwide in a context of growing regional and global demands, especially in Australia. Still, one commonality is that on average, larger and more value-added traffic concentrates at larger, richer, and more urbanised regions, a trend which appears to be more evident when weighting traffic figures to lower the rather artificial importance of bulk traffic, because maritime transport for high value-added goods achieves efficient vessel schedules and frequencies.

Policy orientations can be addressed based on this research. In line with Hall and Jacobs (2012), our results point to the need to motivate maritime transport actors (and beyond, transport and value chain actors) to cultivate a certain embedding with the local level beyond their logistical needs and short-term network configurations. They should be aware that their activity contributes to and benefits from localised socio-economic structures. In turn, such actors may wish to further participate in the related territorial debates when it comes to promoting efficient urban and regional planning. It is the role of the local players (the so-called port community and beyond) to open the door to fruitful discussions with the ocean carriers in order to ensure their mid- or long-term development and sustainable position in maritime networks. As already suggested by Ducruet and Itoh (2015), there is a subtle equilibrium at stake between port-region match and mismatch when it comes to the local embedding of commodity flows. Large urban agglomerations and service centres are, at the same time, important markets dictating the origin and destination of major flows and logistical constraints to the fluid transit of such flows due to land use tensions for port operations. In parallel, certain commodities are more embedded than others in the local port-industrial complex, and a strong port-industry relationship may cause either growth or decline alongside price and geopolitical fluctuations at the international level. Lastly, this new identification of the spatial division of port region specialisation within certain maritime circuits can lead to new policies for interregional cooperation to avoid the growth of inequalities in a context of excessive regional and port competition, especially in Asia.

Further research shall address in more depth the linkages between cargo types and economic activities performed by localities based on more disaggregated figures of regional employment, based on six rather than on three categories. But this will require more thorough investigation into the statistical sources available in each country. Another important possible refinement will be to complement the measurement of maritime flows by adding more exhaustive movements to reach a higher representativeness of the yearly total. At present, this study has captured only a very small portion of annual vessel movements, so that it remains hindered by possible seasonality bias and trade fluctuations. One potential remedy would be to offer a more dynamic view on the way regional economies and maritime flows have co-evolved on a middle and longer-term, possibly going back to the early 1980s as long as vessel types and capacities are reported uniformly by the data source. Expanding the study to other regions of the world such as Europe and Africa (as well as the Atlantic Ocean and the Mediterranean and Black Sea as a whole) would certainly help to verify whether the Pacific Rim trend is emblematic of a more universal one in terms of the ties that bind regional development and maritime transport.

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Country	No. ports	No. port regions	Administrative unit*	Data source for regional data
Australia	62	7	State/TL2	OECD Territorial Database
Canada	7	1	TL2	OECD Territorial Database
Chile	31	11	TL2	OECD Territorial Database
China	81	15	Province	National Bureau of Statistics
India	41	10	State	Ministry of Labour and Employment & Central Statistics Office
Japan	140	40	Prefecture/TL3	Statistics Bureau, Ministry of Internal Affairs and Communications
Malaysia	24	12	State	Department of Statistics
Mexico	16	9	State/TL2	Institudo Nacional de Estadistica y Geografia
New Zealand	14	2	Island/TL2	OECD Territorial Database
Russia	23	1	Federal district	Federal State Statistics Service
South Korea	21	7	TL2	OECD Territorial Database
Taiwan	8	4	Region	National Statistics & Directorate-General of Budget, Accounting and Statistics
United States	50	5	State/TL2	OECD Territorial Database
Total	**518**	**124**		

Table 16.1: Study sample

Traffic indicators		Unit	Regional indicators		Unit
P_DWT%	Share in total national traffic	%	R_Pop(%)	Share in total national population	%
P_Container	Container traffic in regional total	%	R_Density	Regional density / national density	index
P_General	General cargo traffic in regional total	%	R_Unemployment	Regional unemp. / national unemp.	index
P_Liquid	Liquid bulk traffic in regional total	%	R_Primary	Employment in primary activities (LQ)	index
P_Solid	Solid bulk traffic in regional total	%	R_Secondary	Employment in secondary activities (LQ)	index
P_Passenger	Passenger & vehicle traffic in regional total	%	R_Tertiary	Employment in tertiary activities (LQ)	index
P_Inbound	Inbound traffic in region	%	R_GDPpc	GRP per capita / GDP per capita	index
P_Domestic	Domestic traffic in region	%			
P_Degree	No. of connected nodes				
P_Inv_cc	Share of adjacent triangles				

Table 16.2: Selected indicators

Sum of Explained Variance							
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
Eigenvalues	3.286	1.906	1.647	1.511	1.347	1.266	1.075
Variance (%)	19.329	11.212	9.690	8.890	7.926	7.450	6.322
% cumulated	19.329	30.540	40.231	49.121	57.047	64.497	70.819
Components							
Indicators	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
P_DWT%	0.723	0.247	-0.200	0.263	0.293	0.037	0.040
P_Containers	0.688	-0.076	-0.079	-0.108	-0.011	-0.063	0.197
P_General	-0.009	-0.179	0.157	-0.354	0.606	0.346	-0.512
P_Liquid	-0.032	-0.578	0.348	0.492	0.043	-0.094	0.264
P_Passenger	-0.105	-0.275	-0.559	-0.145	-0.084	0.131	0.519
P_Solid	-0.387	0.726	-0.038	0.042	-0.413	-0.199	-0.210
P_Domestic	-0.167	-0.418	0.160	0.577	0.122	-0.213	-0.234
P_Inbound	-0.054	-0.253	0.457	0.169	-0.457	0.263	-0.060
P_Degree	0.658	0.197	0.101	0.338	0.052	-0.247	-0.037
P_Inv_CC	0.136	0.413	-0.164	0.461	-0.073	-0.028	-0.106
R_Primary	-0.697	0.110	-0.204	0.256	0.259	0.024	-0.016
R_Secondary	0.325	0.246	0.704	-0.244	0.049	-0.075	0.256
R_Tertiary	0.235	-0.464	-0.525	0.071	-0.320	0.017	-0.352
R_Pop(%)	0.594	0.208	-0.186	0.273	0.228	0.416	0.094
R_Density	0.590	-0.211	0.042	-0.242	-0.450	0.138	-0.159
R_Unemp	0.157	0.148	0.128	0.232	-0.237	0.623	-0.141
R_GDPpc	0.522	-0.154	-0.071	-0.185	0.024	-0.559	-0.274

Appendix 16.1: Main results of the principal components analysis

Cluster / indicator	C1	C2	C3	C4	C5	C6	C7	C8
	Industrial centre	Value-added city-hub	Agri-bulk hub	Energy centre	Transit centre	Construction centre	Metropolitan gateway	Periphery
R_Primary	-0.113	-0.778	0.419	0.464	0.655	-0.259	-1.247	0.708
R_Secondary	0.749	0.273	-0.433	-0.544	-1.955	-0.054	-0.563	-0.286
R_Tertiary	-0.777	0.201	-0.041	0.344	1.174	0.332	1.918	-0.311
P_DWT%	0.006	1.839	1.065	-0.387	-0.622	-0.660	0.517	-0.432
P_Containers	0.103	1.158	-0.066	-0.376	0.433	-0.250	1.019	-0.717
P_General	-0.230	0.334	-0.960	-0.232	-1.462	-0.370	0.340	2.073
P_Liquid	-0.031	-0.088	-0.745	1.074	-0.241	-0.458	-0.369	-0.582
P_Passenger	-0.156	0.136	-0.452	0.046	4.246	-0.051	-0.179	-0.301
P_Solid	0.191	-1.026	1.479	-0.372	-1.131	0.784	-0.581	-0.423
P_Domestic	-0.301	-0.401	-0.070	1.123	-1.520	-0.430	0.263	-0.095
P_Inbound	-0.160	-0.317	-0.496	0.378	-0.954	0.735	-0.430	-0.371
P_Degree	0.152	1.114	0.957	-0.104	-1.958	-0.423	0.776	-0.965
P_Inv_CC	-0.087	0.554	1.580	-0.026	-0.965	-0.015	-0.222	-0.607
R_Pop(%)	-0.155	1.993	0.898	-0.409	0.080	-0.382	-0.243	-0.106
R_Density	-0.230	0.616	-0.397	-0.365	-0.168	0.648	1.455	-0.575
R_Unemp	-0.322	0.872	0.534	-0.200	-0.670	0.602	-0.803	0.075
R_GDPpc	0.042	0.114	-0.131	-0.090	-1.242	-0.313	2.329	-0.477
	Distribution of port regions and vessel traffic							
No. regions (share for total)	38 (30.6%)	10 (8.1%)	7 (5.6%)	25 (20.2%)	3 (2.4%)	19 (15.3%)	7 (5.6%)	13 (10.5%)
Traffic share	36.8%	18.0%	17.4%	10.3%	0.0%	7.5%	8.5%	1.1%

Appendix 16.2: Main results of the non-hierarchical clustering

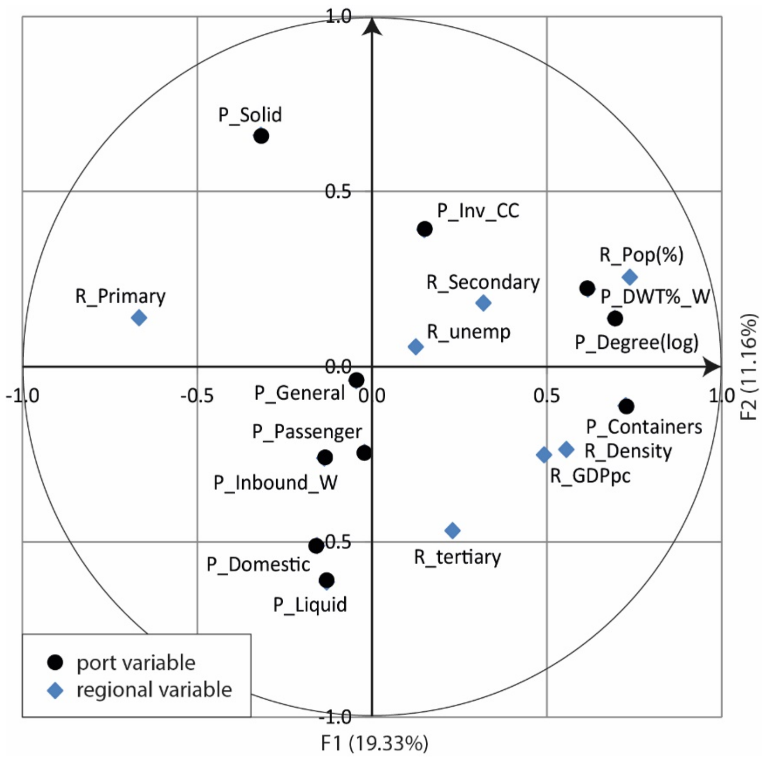

Figure 16.1: Coordinates of port and regional variables on the two main factors

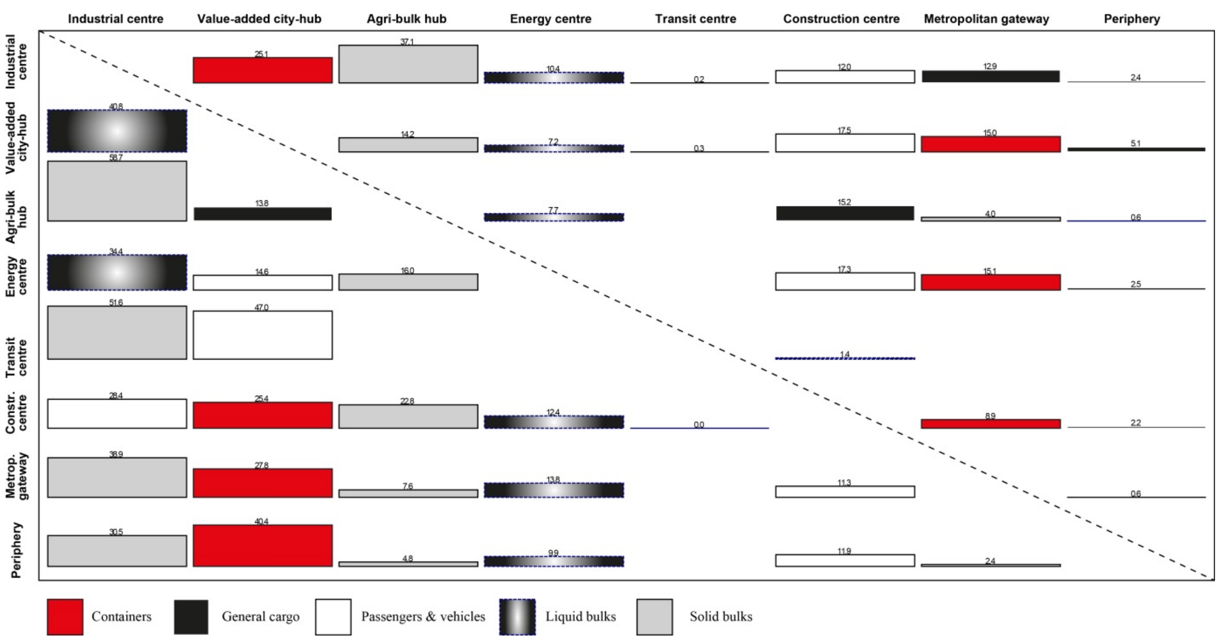

Figure 16.2: Maritime flow specialisation among port region clusters

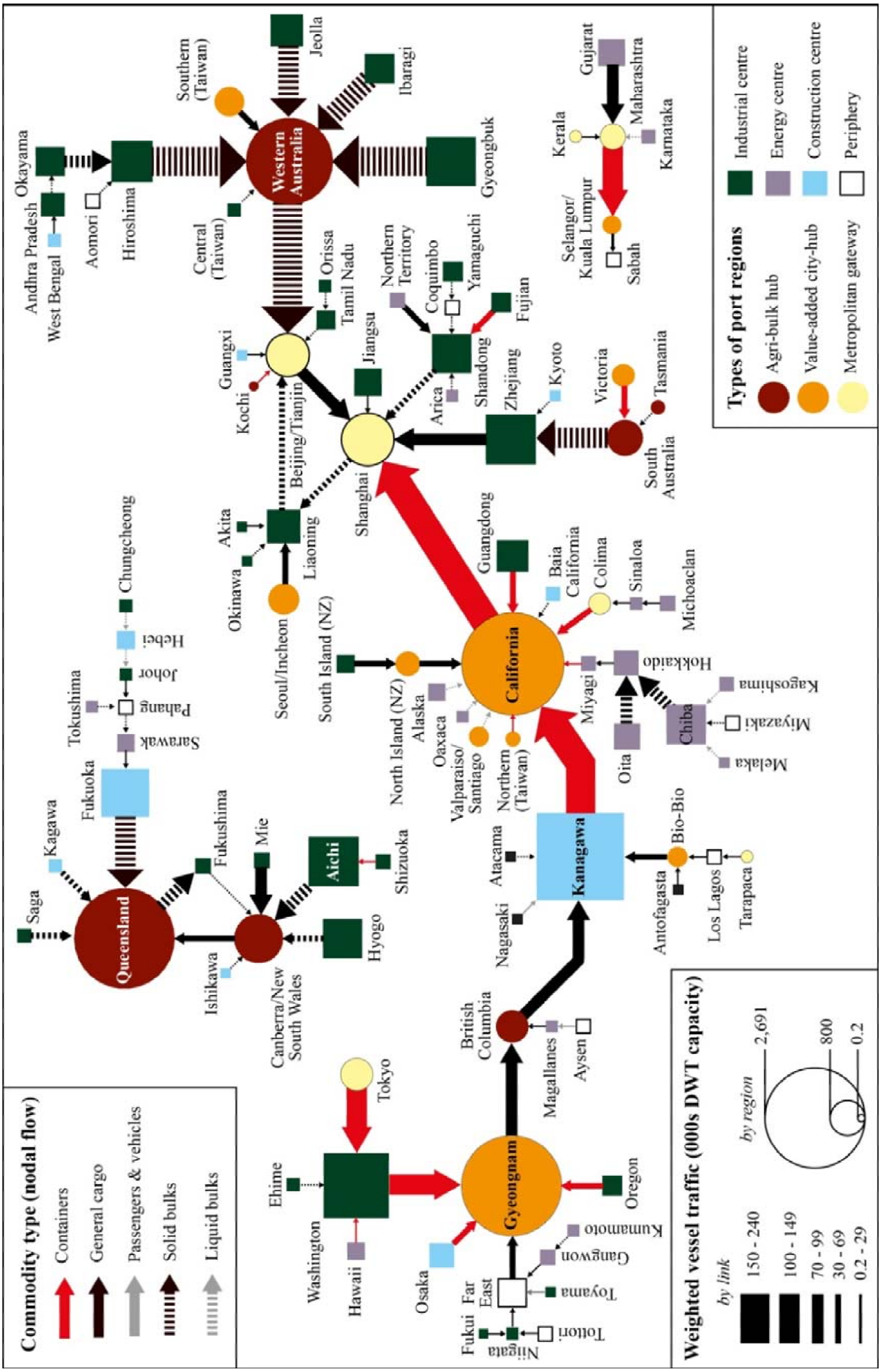

Figure 16.3: Nodal maritime flows among Asia-Pacific port regions