Chapter 2

The impact of ports on their cities

This chapter provides an overview of the impact of ports, their terminals and their related economic sectors and activities. Despite their economic benefits, they also have negative impacts, particularly on the environment, land use and traffic. It assesses how these effects are distributed, and identifies a mismatch between negative impacts, which are mostly localised, and their benefits, which spill over to other regions. This mismatch has intensified in recent decades, due to technological, market and other developments. The concluding section of this chapter assesses future developments that could pose additional challenges to policy makers.

Benefits from ports

The economic benefits of ports are manifold; an overview of the main benefits appears below. First, ports play an essential role in global supply chains, and act as facilitators of trade between port-regions and countries (see "Ports as facilitators of trade"). Ports also provide value added through the economic activities that they and the firms related to ports perform (see "Value added created by ports and port-related industries"). This economic value translates into port-related employment (see "Port-related employment"). Finally, ports also offer spatial clusters for innovation, research and development (see "Ports and innovation"). Port-cities are at the source of these economic benefits, but are by no means the only places that benefit from port activity; this section concludes with an assessment of where the main economic impact is felt (see "Where do ports make an impact?").

Ports as facilitators of trade

Maritime transport costs make up a substantial share of the value of traded goods. On average, 5.1% of the imported value of manufactured goods can be attributed to shipping, compared with 10.9% for agricultural goods and 24.1% for industrial raw materials (Table 2.1). However, transport costs vary widely between various products and their countries of origin and destination. In general, goods shipped in containers have lower transport costs per tonne of merchandise shipped than non-containerised goods, as do goods shipped between major ports on well-travelled trade routes. The costs of shipping a container, for example, vary widely; on some routes, shipping costs can be ten times higher than on others. In the first half of 2008, the cost of shipping a container from Dubai to Singapore was USD 300, as compared with USD 2 849 from Brazil to the United States, a gap that persists even when corrected for differences in distance (Korinek and Sourdin, 2009). The cost of shipping into Africa is by far the highest, representing on average 25% of imported value. Some countries, mostly remote nations with very small markets, face such high maritime transport costs that they represent a significant drag on most exports; the maritime transport costs can account for 43% of the cost of exports from the Christmas Islands, for example (Korinek and Sourdin, 2009).

Table 2.1. Maritime transport costs for main economic sectors

	Maritime transport costs as % of import value	Maritime transport costs (USD/tonne)
Raw materials	24%	33
Agriculture	11%	81
Manufactured goods	5%	174
Crude oil	4%	18

Source: Korinek, J. and P. Sourdin (2009), "Clarifying Trade Costs: Maritime Transport and its Effect on Agricultural Trade", *OECD Trade Policy Papers*, No. 92, OECD Publishing, Paris, http://dx.doi.org/10.1787/220157847513.

Higher maritime transport costs are related to lower external trade volumes. Doubling of maritime transport costs between a given country pair is associated with a decline of 66%-80% in the value of imports and a decrease in trade volume of 26%-28% (Korinek and Sourdin, 2009). A wider range of reductions in trade volume (from 1.5% to 38%) was found in a study of Spanish exports to Poland and Turkey (Martinez-Zarzoso and Nowak-Lehmann, 2007). Yet another study identified that a 10% increase in bilateral maritime transport costs (USD/tonne) is associated with a decrease of approximately 8% in the value of agricultural imports on average. However, between products, the variation in transport costs can range from a 1.7% decrease for products of animal origin to a 11%

decrease for cereals, given a decrease of 10% in transport costs (Korinek and Sourdin, 2010). Large trade-transport cost elasticities (2.3-2.5) have repeatedly been found in different studies (Limao and Venables, 2001; Martinez-Zarzoso, Garcia-Menendez and Suárez-Burguet, 2003; Martinez-Zarzoso and Suárez-Burguet, 2005). External trade between countries can depend not only on maritime transport costs but also on the two countries' GDP, whether or not they share a common language or membership in a major regional trading agreement and on shipping distance.

In comparison, in land-locked countries, the costs of trade are higher. A study of 97 developing countries (of which 17 were landlocked) estimated that transport and insurance costs are twice as high for landlocked countries as coastal countries (Radelet and Sachs, 1998). This is related to the larger share of land transportation, considering that it is seven times more expensive to transport goods by land than by sea (Limao and Venables, 2001). As a result, a landlocked country trades approximately 80% less than a non-landlocked country (Raballand, 2003; Martinez-Zarzoso and Suárez-Burguet, 2005), and median land-locked countries have only 30% of the trade volume of the median coastal economy (Limao and Venables, 2001). However, there are considerable differences among land-locked countries: the greater the number of options for a land-locked country, the more the land-locked country imports, because it has more bargaining power to reduce transit costs than land-locked countries that only have connections with one seaport (Raballand, 2003). Examples of land-locked countries with multiple port options are Switzerland, Austria and the Czech Republic: these are highly contested hinterlands by ports as diverse as Rotterdam, Hamburg, Koper, Trieste and Constantza (Merk and Hesse, 2012).

An important determinant of the relation between transport and trade is time. Each additional day in transit reduces trade volumes by 1%, leads to an increase in the freight rate of USD 56 and adds 0.8% on average to the value of manufactured goods (Djankov, Freund and Pham, 2006; Hummels, 2001). A 10% increase in time reduces bilateral trade volumes by 5%-8% (Hausmann, Lee, Subramanian, 2005) and leads to a reduction in trade value of 5%-25% (Nordas, Pinali, Geloso Grosso, 2006). In addition, uncertainty in the shipping times has a bigger impact on decreases in trade. Korinek and Sourdin (2011) found that the reason for a delay makes a difference in trade impacts – if the delay is due to administrative reasons, for example, the trade impact is greater than if it is due to distance. This could be attributed to greater uncertainty in the case of the administrative issues; delays due to distance can be estimated and more easily allowed for. Delays matter more for time-sensitive perishable goods. Shipments of livestock are the most time-sensitive, whereas shipments of coal are the least. This can be derived from a measure of industry sensitivity to shipping times that was formulated by Hummels and Schaur (2012), reflecting the premium for air shipping that firms in an industry are willing to pay to avoid an additional day of ocean transport. Industries sensitive to shipping times are also sensitive to cargo logistics (Table 2.2). Moreover, firms tend to shift to more expensive air shipping when uncertainty in ocean shipping increases (Clark, Dollar and Micco, 2004).

Port efficiency is one of the main determinants of international transport costs. Of six different port characteristics, including port infrastructure, private sector participation and inter-port connectivity, efficiency was found to be the most important (Wilmsmeier, Hoffmann and Sanchez, 2006). Various studies have quantified the widely varying effects of increased port efficiency on the one hand, and decreased transport costs and increased trade volumes on the other hand (see Table 2.3). The role of port efficiency in reducing costs of trade is confirmed by other studies (Sanchez et al., 2003; Nordas and Piermartini, 2004).

Table 2.2. Time sensitivity of economic sectors

Industry sector	Time sensitivity index
Livestock and livestock products	2.590
Chemicals and allied products	1.659
Miscellaneous manufactured products	1.257
Stone, clay, glass and concrete products	1.224
Scientific and professional instruments	1.171
Fabricated metal products	1.100
Non-metallic minerals	0.998
Machinery, excluding electrical	0.905
Rubber and plastics products	0.904
Paper and allied products	0.881
Electrical machinery	0.788
Primary metal products	0.743
Printing, publishing and allied products	0.703
Apparel	0.666
Crude petroleum and natural gas	0.665
Transportation equipment	0.654
Food and associated products	0.591
Furniture	0.585
Fish, fresh or frozen and other marine products	0.577
Lumber and wood products	0.577
Textiles	0.575
Agricultural products	0.433
Petroleum refining and related products	0.359
Tobacco	0.279
Forestry products	0.268
Metallic ores and concentrates	0.000
Coal and lignite	0.000

Source: Hummels, D. and G. Schaur (2012), "Time as a Trade Barrier", *NBER Working Paper 17758*, National Bureau of Economic Research, Cambridge, MA.

Table 2.3. Link between port efficiency and trade/freight costs

Port efficiency measure	Impact on trade	Characteristics	Source
Double port efficiency	32% increase of trade volume	Top 100 non-US and top 50 US ports; 1991-2003	Blonigen and Wilson 2008
From 75th to 25th percentile	25% increase of trade volume	59 countries, 1996-2000	Clark et al., 2004
From lowest score to highest	Decrease of freight cost by 25.9%		Wilmsmeier et al., 2006
One point rise on WEF-index	4.3% reduction in *ad valorem* transport costs		Abe and Wilson, 2009
Make all ports as efficient as the most efficient port	82.5% increase in export volumes	14 Brazilian ports	Haddad et al., 2010

Note: The WEF-index refers to the port quality index of the World Economic Forum, ranging from 1 to 7.

Source: Authors'calculations based on Blonigen, B. and W. Wilson (2008), "Port Efficiency and Trade Flows", *Review of International Economics*, Vol. 16, No. 1, pp. 21-36; Clark, X., D. Dollar and A. Micco (2004), "Port Efficiency, Maritime Transport Costs and Bilateral Trade", *Journal of Development Economics*, Vol. 75, No. 2, pp. 417-450; Wilmsmeier, G., J. Hoffmann and R. Sanchez (2006), "The Impact of Port Characteristics on International Maritime Transport Costs", *Research in Transport Economics*, Vol. 16, pp. 117-140; Abe, K. and J. Wilson (2009), "Weathering the Storm: Investing in Port Infrastructure in Lower Trade Costs in East Asia", *World Bank Policy Research Paper*, No. 4911, World Bank, Washington DC.; Haddad, E. et al. (2010), "Regional Effects of Port Infrastructure: A Spatial CGE Application to Brazil", *International Regional Science Review*, Vol. 33, pp. 239-263.

Other port characteristics also determine maritime transport costs. Among the main characteristics identified are:

- **Port infrastructure**. Onshore infrastructure accounts for 40% of predicted transport costs for coastal countries, and various studies indicate a link between port infrastructure and maritime transport costs. Limao and Venables (2001) calculate that a country with relatively poor infrastructure (around the 75th percentile) that upgraded to the 25th percentile would reduce transport costs by between 30% and 50%.

  According to Martinez-Zarzoso, Garcia-Menendez and Suárez-Burguet (2003) an improvement of 10% in the port infrastructure of a destination country lowers transport costs by 1.4%; and an increase of port infrastructure of one standard deviation reduces the freight rate by USD 225, following calculations of Wilmsmeier and Hoffmann (2008). It should be noted that the port infrastructure of exporters is more important for transport costs than the importers' (Nordas and Piermartini, 2004; Korinek and Sourdin, 2011).

- **Port centrality**. If a country doubles its centrality in liner shipping networks, achieving a significant increase in direct liner services to a wider range of countries, transport costs can decrease by up to 15.4% (Wilmsmeier and Sanchez, 2009). An increase of connectivity of one standard deviation implies a potential reduction of the freight rate of USD 287 (Wilmsmeier and Hoffmann, 2008).

- **Port congestion**. A 10% increase in port congestion leads to 0.7% increase in maritime transport costs (Abe and Wilson, 2009). This is related to the quality of logistics services in ports. Devlin and Yee (2005) document the wide variation in logistics costs in Middle Eastern and North African countries and how they can influence shipping costs. Inefficient trucking services leave longer stand times on the dockside and costly inventory accumulation, as well as reduce export volumes, leading to less frequent shipping services.

The impact of port infrastructure and efficiency differs depending on industry and the stage of economic development. Martinez-Zarzoso, Pérez-Garcia and Suárez-Burguet (2008) find that a 1% improvement of infrastructure in the destination country lowers transport costs by 0.20% on average. However, that infrastructure variable is not significant for high value added sectors, such as household appliances and vehicle parts generally sold to the most developed countries, which already have the highest levels of infrastructure quality. In addition, infrastructure benefits middle-income countries more than lower-income countries. For a lower-middle-income country, a one-unit improvement in port infrastructure on the World Economic Forum's Global Competitiveness Report index for port infrastructure (ranging from 1 to 7) is associated with an estimated increase in trade of 139%; the figure is 236% for upper-middle income countries and 171% for high-income countries. This may be due to their ability to take advantage of trade-facilitating investments, which lower-income countries may be less able to do (Korinek and Sourdin, 2011).

Higher external trade can translate into higher economic growth. An overview of existing studies on the impacts of trade on economic output and growth indicates that the macroeconomic evidence provides support for the positive and significant effects of trade on output and growth. Microeconomic evidence lends greater support to the exogenous effects of productivity on trade, as compared with the effects of trade on productivity (Singh, 2010). In any case, high trade costs inhibit a country from taking advantage of potential gains from specialisation and trade in promoting economic development (Markusen and Venables, 2007).

Value added created by ports and port-related industries

Such value added can be substantial. For example, the value added of the port cluster in Rotterdam in 2007 was calculated at EUR 12.8 billion, representing approximately 10% of regional GDP. Even higher shares of regional and national GDP are attained for the port cluster of Le Havre/Rouen, which accounted for more than 21% of regional GDP in 2007, and the port cluster of Antwerp, which generates around 3% of the Netherlands' GDP (Merk et al., 2011). These numbers include direct and indirect value added, the categories most frequently covered in studies on the economic impact of ports. In general, four different types of impact are distinguished: direct, indirect, induced and catalytic. Direct impact covers jobs and income generated by the construction and operation of the port. Indirect impacts are the employment and impact of the suppliers of goods and services, and induced impact is the employment and income generated by the spending of income by employees created by direct and indirect effects. Catalytic impact is generated by the port as a driver of productivity growth and attractor of new firms (Ferrari, Percoco and Tedeschi, 2010).

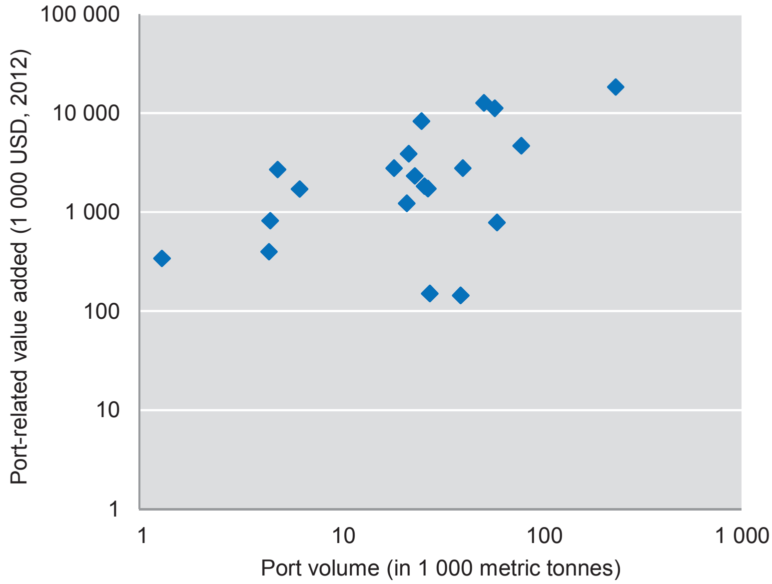
The larger the port, the more value added is created by the port and port-related sectors. A meta-study of approximately 150 port impact studies conducted for this report indicates that on average, one tonne of port throughput is associated with USD 100 of economic value added. Two-thirds of the ports in the sample have between USD 50 and USD 250 value added per tonne of port throughput (Merk, forthcoming). This number includes direct and indirect port value added. Our analysis, shown in Figure 2.1, which for reasons of comparability shows only US ports with port impact studies with similar methodology, indicate that larger ports have larger port-related value added (direct and indirect). Much depends on the types of goods that are handled in the port. There are very large differences in direct value added associated with different categories of goods handled in ports. Dry bulk and liquid bulk generally generate more limited value added per tonne than project cargo, general cargo and containerised cargo. Analysis of value added per cargo types in US ports shows that these values can vary by a factor of 10: one tonne of grain handled generates USD 20 on average; USD 220 for automobiles and USD 90 for containerised cargo (Table 2.4).

Table 2.4. Value added per cargo type (USD per metric tonne)

Cargo type	Average	Minimum	Maximum
Automobiles	220	116	331
Containers	90	40	149
Steel	60	23	118
Petroleum	45	11	183
Grain	20	9	37

Source: Merk, O. (forthcoming), "Meta-analysis of Port Impact Studies", *OECD Regional Development Working Papers*, OECD Publishing, Paris.

Figure 2.1. Relation between value added and port volume (2012)



Source: Merk, O. (forthcoming), "Meta-analysis of Port Impact Studies", *OECD Regional Development Working Paper*, OECD Publishing, Paris.

Ports can have large indirect economic effects (backward linkages). Our series of case studies, using a uniform methodology, found multipliers ranging from 1.13 to 2.47 (Table 2.5). A multiplier of 2.47 means that each additional euro spent in the port leads to EUR 1.47 additional demand for suppliers to the port cluster. These multipliers measuring the backward linkages of the ports sector were calculated by integrating port clusters into national input output-tables and assessing the inputs and outputs from the port cluster economy. The indirect impact of the ports of Rotterdam and Antwerp on the national economy was smaller than those found for the other European ports, namely Hamburg, Le Havre and Marseille. This could be explained by the fact that Rotterdam and Antwerp are very large ports in a relatively small country, and that a considerable part of the indirect economic effects of these ports may be benefiting other countries and not showing up in the multiplier. Overall, ports were found to have strong linkages with transport, storage and communication sectors; as well as with coke, refined petroleum and nuclear fuels and chemicals.

Table 2.5. Overview of port multipliers (backward linkages)

	Leontieff multiplier
Le Havre/Rouen	2.47
Marseille	2.01
Mersin	1.79
Hamburg	1.71
Antwerp	1.18
Rotterdam	1.13

Source: OECD Port-City case studies: Merk and Bagis (2013), Merk and Comtois (2012), Merk et al. (2011), Merk and Hesse (2012), Merk and Notteboom (2013).

Port-related industries can be differentiated according to firms providing services necessary to maritime trade (*port-required industries*), firms attracted to the region because of the presence of a port (*port-attracted industries*) and firms that have expanded markets by exporting through the port (*port-induced industry*), based on Yochum and

Agarwall (1987, 1988). Port-required industries include transportation services and port services (such as terminal operations, stevedoring, towage, etc.). Port-attracted industries are either firms that export commodities, or firms that import products or raw materials (*e.g.* refineries, steel factories). "Port-induced industries" is a much wider category and generally more difficult to capture, because it is difficult to assess their dependence on the port. Generally, direct impacts of ports will include impacts on port-required industries, whereas indirect impacts will cover port-attracted and port-induced industries. Some studies differentiate port-related industries (required or attracted) into industries that need direct quay access and those that do not, such as the national port monitor published annually in the Netherlands. A related concept is the seaport cluster, which can be considered to consist of port-required and port-attracted industries.

Ports tend to attract firms in a variety of industries, often including transport and logistics, warehousing and storage. Several ports are also sites for resource-intensive industries, such refineries, chemicals, steel and coal; and aerospace and renewable energy production, including offshore wind energy and biomass production. However, a variety of practices exist, apparently determined by available space, port strategies and also the structure of the economy of a region. Regional industrial specialisations correlate with (and may determine to some extent) the types of cargo handled in the port. Regions that specialise in agriculture, for example, have ports specialised in the handling of agricultural products, etc. (Ducruet, Itoh and Joly, forthcoming).

Strong inter-linkages can exist between ports and related industries. This can be concluded from our assessment of the backward economic linkages of various port clusters; the main economic sectors linked to the port sector – and the intensity of these links – are indicated in Table 2.6. Many of these links are also localised. Large chemical clusters, such as in Antwerp, Rotterdam and Tarragona, have developed in and around their respective ports. The port represents the principal access point for raw materials for the manufacturing of chemicals. The impact of the port on the economic success of the chemical clusters is also considered fundamental for exports (EPCA, 2007). These industries could in turn also be interlinked. Plans to set up a heavy steel and metal industry in Dunkirk were accompanied by large energy suppliers needed to supply these industries, and firms, such as Coca-Cola, interested in taking advantage of the proximity of intermediate products (such as white iron, used for producing cans for drinks) produced by other firms on the territory (Boutillier, Laperche and Uzunidis, 2011).

Table 2.6. Intensity of economic links between selected ports and other sectors

	Le Havre-Rouen	Marseille-Fos	Hamburg	Rotterdam	Antwerp
Transport equipment	3.28	2.83	2.47	1.04	1.18
Food, beverages and tobacco	n.a.	2.69	2.22	1.07	1.05
Coke, refined petroleum, nuclear fuel	2.76	2.67	2.15	1.24	1.20
Other manufacturing	2.47	2.57	1.90	n.a.	n.a.
Transport, storage and communication	2.02	1.92	1.79	1.25	1.39
Financial intermediation	1.96	1.96	1.64	n.a.	n.a.
Wholesale and trade	2.02	1.90	1.31	1.03	1.09
Non-market services	1.89	1.39	1.31	n.a.	n.a.
Chemical, rubber and plastics products	n.a.	n.a.	n.a.	1.34	1.36
Manufacturing metals/metal products	n.a.	n.a.	n.a.	1.06	1.07
Electricity, gas and water supply	n.a.	n.a.	n.a.	1.17	1.13
Electrical and optical instruments	n.a.	n.a.	n.a.	n.a.	1.03
Mining, quarrying and energy supply	2.31	2.45	n.a.	n.a.	n.a.
Construction	2.30	2.17	n.a.	n.a.	n.a.

Source: OECD Port-City case studies: Merk and Bagis (2013), Merk and Comtois (2012), Merk et al. (2011), Merk and Hesse (2012), Merk and Notteboom (2013).

Value added of industrial development in ports can be on a par with or even higher than those of direct port value added. The four largest European ports all have approximately half of their value added concentrated in non-transport-related industrial sectors. In Antwerp, the chemical sector alone represents more than a quarter of the total direct and indirect value added of the port cluster. Moreover, various large ports show indications of synergetic cluster effects; these can be measured through the intensity of economic linkages between the sectors within the port area: the backward linkages multiplier. In the ports of Rotterdam and Antwerp, substantial intra-port economic interlinkages were found (Table 2.7).

Table 2.7. Economic linkages within the port area (Rotterdam, Antwerp)

	Rotterdam	Antwerp
Total	1.03	1.05
Chemical, rubber and plastic products	1.08	1.10
Transport, storage and communications	1.07	1.13
Coke, refined petroleum and nuclear fuel	1.05	1.05
Electricity gas and water supply	1.04	1.04
Manufacturing n.e.c.	1.02	1.02
Food, beverages and tobacco	1.04	1.02
Manufacture basic metals/metal products	1.02	1.02
Transport equipment	1.01	1.05
Wholesale and retail trade, auto repair	1.01	1.03

Source: Merk, O. and T. Notteboom (2013), "The Competitiveness of Global Port-Cities: The Case of Rotterdam/Amsterdam, the Netherlands", *OECD Regional Development Working Papers*, No. 2013/08, OECD Publishing, Paris, http://dx.doi.org/10.1787/5k46pghnvdvj-en.

The value added generated by cruise activities is relatively limited. Cruise port-impact studies generally look at three categories of spending resulting from cruise tourism: cruise line spending, crew spending and passenger spending. Some reports claim that the "crew" category is often skewed and fails to measure crew members who come ashore (Vaggelas and Pallis, 2010). Passenger spending, nonetheless, generally accounts for the largest share of revenues from cruise tourism in ports of call, particularly in island economies (*i.e.* the Caribbean). The average spending per cruise passenger in a port amounts to USD 100, based on our meta-assessment of cruise port impact studies covering over 75 different ports. The average economic contribution per passenger in a cruise port is USD 200, although there is a large variation of values, so it is difficult to generalise from these findings (Table 2.8). The largest absolute economic contribution of cruise shipping was identified in the port of Piraeus in Greece, with a report economic turnover of USD 690 million. Although this is a substantial amount, it does not come close to the economic value added generated by cargo and industrial functions in many ports. For most seaports, the share or cruise-related value added remains fairly small.

Table 2.8. Economic contribution of cruise shipping

	Average	Minimum	Maximum
Spending per cruise passenger (USD)	100	34	309
Turnover per passenger (USD)	200	20	1 868

Source: Merk, O. (forthcoming), "Meta-analysis of Port Impact Studies", *OECD Regional Development Working Papers*, OECD Publishing, Paris.

There are links between port activity and global firms, in particular maritime services, such as ship finance, maritime insurance, maritime law and maritime consultancy. The location and connectivity of multi-office firms in these sectors follow global cities hierarchies more closely than port hierarchies, as indicated for example by relatively strong positions of non-port-cities, such as Paris and Madrid, although the high ranks of Rotterdam and Hamburg present the exceptions to the rule (Jacobs, Ducruet and De Langen, 2010). For these economic activities, urban attractiveness is a more important criterion than the presence or size of a port, as illustrated by the case of London, a city where most port functions have disappeared in recent decades, but which has developed as one of the leading world cities in advanced maritime services, with the highest connectivity in terms of multi-office maritime services firms. Studies on the command centres in container shipping confirm that such high value added functions are often located in port-cities, but that being a port-city is no guarantee for attracting such functions (Verhetsel and Sel, 2009). Such services can provide large value added; the economic contribution of maritime business services to the British economy was estimated at approximately GBP 1.5 billion in 2011 (Oxford Economics, 2012).

In comparison with seaports, airports tend to attract more high-value-added activities, such as headquarter functions and high technology jobs. These are related in many parts of the world to hub airports that are able to offer a wide variety of inter-continental flights. It was estimated in the early 2000s that across all major US cities, the location of a hub airport in a given region attracted about 12 000 extra high-technology jobs (Button et al., 1999). Headquarters are important for a regional economy because they can in turn attract high-value-added business services. A study on the location of headquarters in the EU showed that a 10% increase in the provision of intercontinental flights leads to a 4% increase in the number of headquarters located in the urban area (Bel and Fageda, 2008). Airports, in contrast to seaports, attract a large cluster of business services, commercial retail, hotels and headquarters. This can be explained by the fact that servicing business passengers is the core business of most major airlines and airports, unlike seaports. Air cargo is mostly limited to high-value cargo. The combination of sea- and airports can create synergies for certain businesses. O'Connor (2010) has observed that more diversified gateways (*i.e.* those with multiple airports and seaports within a radius of 70 kilometres from the "core") generate more traffic and larger logistics sectors than more specialised gateways (*i.e.* those handling either air or sea freight). At the same time, the air and sea cargo sectors are in practice fairly disintegrated (*e.g.* for Europe [Ducruet and Van der Horst, 2009]). Some port authorities, such as New York/New Jersey, Portland and Seattle, also administer airports, which can generate substantial shares of value added.

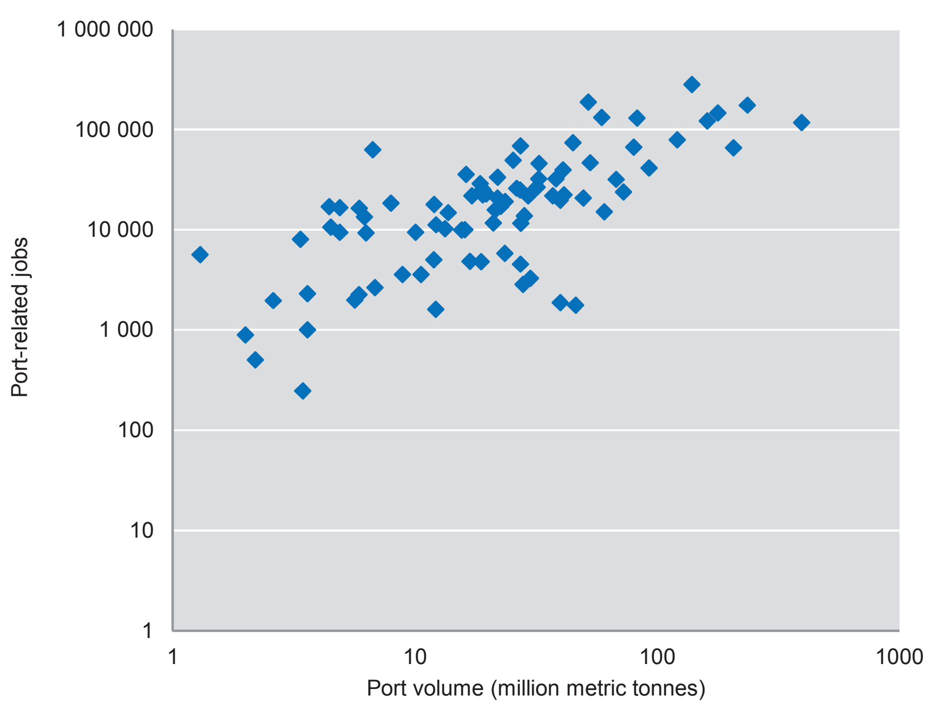
Port-related employment

Port industries require local employment, but this is relatively marginal in comparison with the wider regional economy in which ports operate. Even in the largest ports, port and port-required employment rarely exceeds a few thousand jobs. Several trends, including containerisation, automation and economies of scale, have made port operation and cargo handling increasingly capital- and land-intensive, and decreasingly labour-intensive. In recent decades, many ports have shed labour to become more productive and competitive. Direct port value added is also relatively small. The economic impact of a port is context specific and to some extent determined by its specialisation. Some commodities generate more value added for a port than others, with general cargo generating more value added per tonne of throughput and crude oil and containers the least in North West European ports, for which such an analysis was conducted (Haezendonck, Coeck, Verbeke, 2000).[1]

The larger the port, the more port-related employment. A meta-study of about 150 port impact studies conducted for this report indicates that on average, one million tonnes of port throughput is associated with 800 jobs. This number includes direct and indirect port jobs and should be interpreted with caution, as it is based on port impact studies that use different definitions of ports and apply different methodologies. The variation of results is fairly large, but two-thirds of the ports in the sample have between 200 and 1 500 jobs per million tonne of port cargo. A few outliers distort the correlation, but in general, the link between cargo volume and port-related employment holds (Figure 2.2.). With respect to cruise ports, the average number of direct and indirect jobs is 3.5 per thousand cruise passengers.

Port-attracted industries can represent a relatively large share of employment and value added of port regions, *e.g.* up to 10% of employment and 16% of value added of the main port regions in northwest Europe. Much depends on which sectors are included in the port-attracted industries. Some studies follow the boundaries of the port area in which case the industries located there are considered port-attracted industries.[2] Annual studies of the National Bank of Belgium on the economic impact of Belgian ports incorporate all activities located in the port areas (Mathys, 2010). Firms that may be located in the port need not in fact have a relation to the port, whereas other firms could be located near the port because they need good access to it. For this reason, a functional approach is often used to capture the port-attracted firms in certain defined regional boundaries. Input/output-models are frequently used to identify intersectoral links with the port, that is, their backward and forward linkages. Much depends on the port in question, but usually seaports have inter-linkages with the transport equipment sector and the wholesale and retail sector. The challenge is to find a coherent demarcation of port-attracted industries: what one study may consider port-related industry may be different in another. To overcome this discretionary distinction between port-related and non-port-related industries, an alternative approach has been to use differences in economic specialisation between port regions and non-port regions as a way to determine which sectors to consider as port-related sectors. This approach has been applied to Italy (Musso, Benacchio and Ferrari, 2000).

Figure 2.2. Relation between employment and port volume



Source: Elaboration based on compiled dataset of existing port impact studies, Merk (forthcoming).

At the same time, port throughput is positively correlated to employment in port regions, according to our analysis of European port-regions. This study indicates that an increase of one million tonnes of port throughput is associated with an increase in employment in the port region of 0.0003% (Ferrari et al., 2012). This means that in a region with one million employees, employment would increase by 300 units; in the long run, this increase would be 7 500 units. This impact is slightly larger on industry than on service employment. These conclusions are based an evaluation of the impact of port activity on regional employment in a sample of 560 regions in 10 European countries, 100 of which were home to one or more ports, from 2000-06. If liquid bulk is not included in port-throughput numbers, the employment impact in the region doubles: an increase of one million tonnes of port throughput is then associated with a regional employment increase of 600 units. This finding confirms the fact that only a few jobs are needed to handle liquid bulk, because of the loading and unloading of a large share of it by pipelines. No significant employment impact was found for (ferry) passengers.

Ports and innovation

Ports determine to some extent the direction of research and innovation. Port-cities are dominant in port-related patents, such as shipping, petroleum and hoisting/lifting. Almost all the ten world regions with the highest number of patent applications in shipping are home to one or more large global ports, including Houston, Los Angeles/Long Beach, Tokyo, Oakland and Rotterdam (Table 2.9). Of these regions in the top ten for shipping patents, only the Zürich region does not have a port. The regions of Stockholm and Rogaland have ports (Stockholm and Stavanger respectively), but they are not among the top 125 world ports. Port-regions are also strong with respect to port-related patents in a wider sense. These include patents in technologies used in the port sector (constructions and hoisting-lifting-hauling), or important commodities handled in port areas, such as petroleum and foodstuffs.

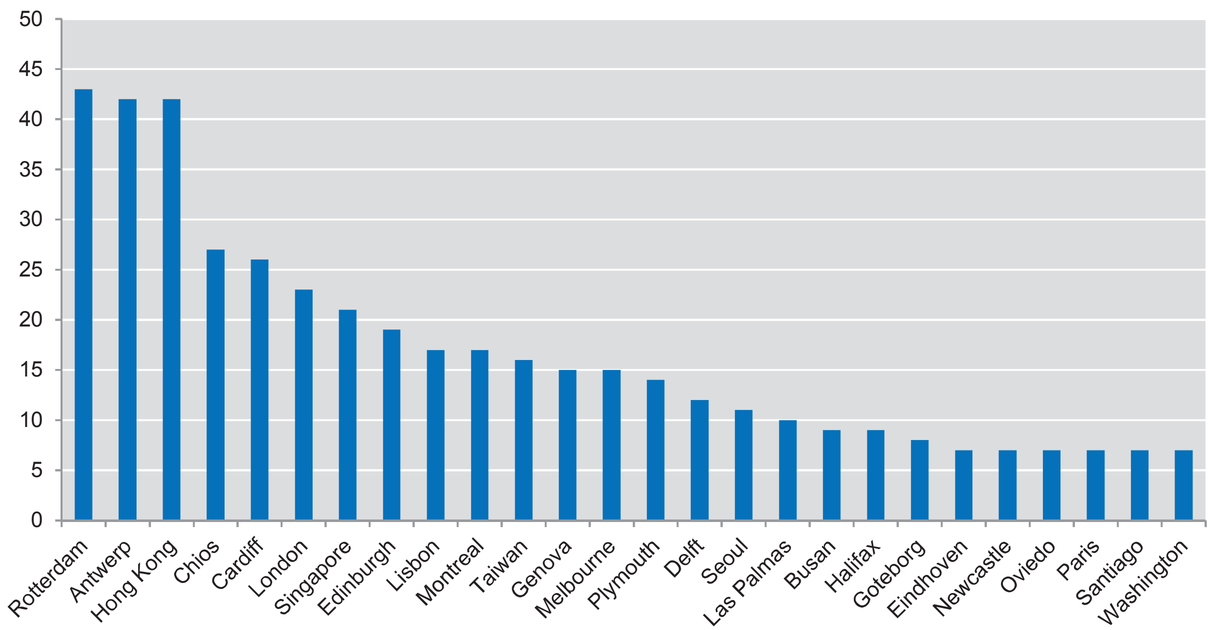
Table 2.9. Top 10 world regions for shipping patents (2005-07)

Region	Percentage of shipping patents	Top 125 ports
1. Houston-Baytown-Huntsville (US)	3.9%	Houston
2. Los Angeles-Long Beach-Riverside (US)	2.1%	Los Angeles and Long Beach
3. Tokyo (JP)	2.1%	Tokyo, Yokohama and Chiba
4. San Jose-San Francisco-Oakland (US)	2.0%	Oakland
5. Zuid-Holland (NL)	1.9%	Rotterdam
6. Västra Götalands län (SE)	1.5%	Gothenburg
7. Zurich (CH)	1.4%	
8. Stockholm (SE)	1.4%	
9. New York-Newark-Bridgeport (US)	1.3%	New York/New Jersey
10. Rogaland (NO)	1.2%	

Source: Authors'elaborations based on OECD (2014), "Patents by main technology and by International Patent Classification (IPC)", *OECD Patent Statistics* (database), http://dx.doi.org/10.1787/data-00508-en, (accessed 20 April 2013).

Port-related research is primarily conducted in universities in port-cities, and not in most other cities. This can be concluded from a count of the city affiliations of the authors and co-authors of 576 port-related articles published in leading peer-reviewed academic journals between 1997 and 2011 (Figure 2.3). Rotterdam ranks highest on this count, closely followed by Antwerp and Hong Kong. As becomes clear from this ranking, port-related research is conducted is strongly associated with the presence of ports: almost all the highly ranked cities in the list are port-cities and varies widely from worldwide university rankings, in which leading US and UK universities, such as Harvard, Oxford and Cambridge, tend to figure. Several of these port-cities, such as Hamburg, Copenhagen and Marseille, also offer maritime business education programmes, such as maritime MBAs.

Figure 2.3. Leading cities in port-related research

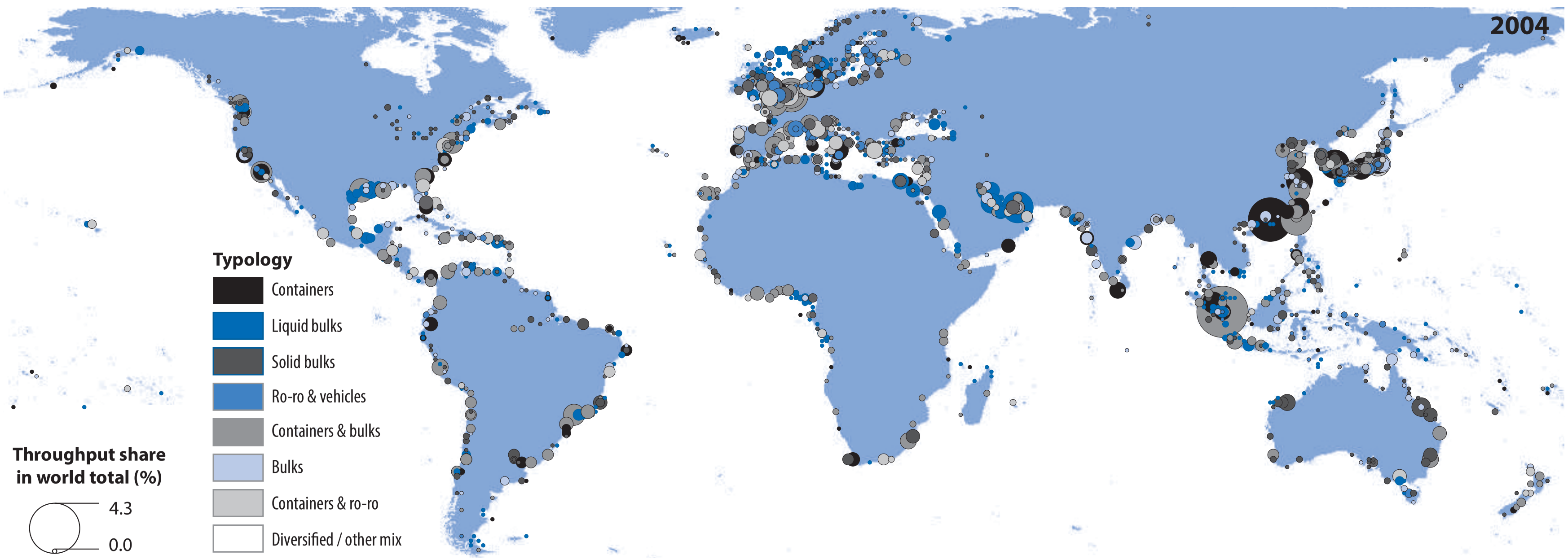


Source: Authors' data compilation based on list of articles mentioned in Pallis, A., T. Vitsounis, P. de Langen (2011), "Port Economics, Policy and Management : Content Classification and Survey", *Transport Reviews : A Transnational Transdisciplinary Journal*, Vol. 31, No. 4, pp. 445-471; www.porteconomics.eu.

Where do ports make an impact?

Port-cities benefit from part of the economic impacts of ports. Most of the direct port-related value added is still created in port-cities. They also benefit from the effects of clustering industries in a port area, and the economies of scale and knowledge transfer associated with it. Several resource-intensive industries continue to be attracted by port areas, because location in a port limits their transportation costs. Port traffic is very sensitive to the local economy in which it is handled: in larger and richer regions with large tertiary sectors, the port volumes are often more diversified and include more high-value-added goods, such as containers and consumer goods, whereas agricultural and industrial regions are usually more specialised in bulk traffic (Ducruet et al., forthcoming). This is a relevant finding that could explain the wide variety of port specialisation profiles all over the world (Figure 2.3.).

Figure 2.4. Port specialisation profiles



Source: Authors' elaboration based on dataset from Lloyds' Marine Intelligence Unit (LMIU).

However, most of the indirect and catalytic effects of ports take place outside port-regions. Firms in other regions also benefit from efficient ports, in that they reduce their transport costs and facilitate imports and exports. Backward and forward linkages of port clusters extend to a whole country; the impact is usually fairly small in the port-city itself. This can be concluded from analysis conducted in the various OECD Port-Cities case studies, in which port clusters were integrated in multi-regional input/output-tables, which makes it possible to identify where main linkages take place. Our analyses show that only a very limited part of these linkages takes place in the port or the port-region, with a larger share in the main economic centre of the country, which could be relatively far away from the port, *e.g.* Ile-de France for the ports of Le Havre and Marseille; and Bavaria and Baden-Württemberg for the port of Hamburg. Port-related employment has tended to partly shift to other regions as well, in parallel with the relocation of logistics activity further away from ports. In many cases, spillovers take place not only to other regions in the same country, but also into other countries. The port of Rotterdam, for example, plays an important role for German industries, and several European ports for the land-locked central European countries.

Negative impacts of ports

Environmental impacts

There are a variety of environmental impacts related to port activity. These impacts are related to shipping activity in a port, the activity on the port land itself and the environmental impacts of hinterland transport to and from ports. The main impact falls on air emissions, water quality, soil, waste, biodiversity, noise and so on. These environmental impacts can have severe consequences for the health of the population of the port-city, especially for the poorer parts of port-cities.

Air emissions

Maritime shipping is the most carbon-efficient form of transport in terms of grammes of carbon dioxide emitted per cargo ton, compared to rail, road or air transport (WSC, 2009), but the sheer scale of maritime transport activities generates massive quantities of emissions. These affect the composition of the atmosphere, the climate and human health (Corbett et al. 2007; Eyring et al., 2005). The main compounds of concern emitted by shipping and port operations are sulphur dioxide (SO_2), carbon dioxide (CO_2), black carbon (BC), carbon monoxide (CO), nitrogen oxides (NO_x), and various kinds of particulate organic matter (OECD, 2011).[3] Sulphur is at the origin of many particulate matters that epidemiological studies have consistently linked with a range of illnesses, including pulmonary diseases and premature death (Eyring et al., 2010). Corbett et al. (2007) have estimated that, because the vast majority (70%) of these emissions occur within 400 kilometres of coastal communities, shipping emissions cause around 60 000 early mortalities each year, mainly in the seaside areas of East Asia, South Asia and Europe. Uncertainties in the data and methods used to calculate mortality limit this estimate to within the range of 20 000-104 000 (Eyring et al., 2010), but the impacts fall within a troubling order of magnitude.

Due to the huge differences in terms of air emission measurements and port characteristics, it is difficult to make comparisons of air emissions at each port. Several ports publish a sustainability report presenting different indicators of their environmental impacts, including air emissions, including Los Angeles, Long Beach, Houston, Vancouver, Seattle, Sydney, Auckland, Hong Kong, Gothenburg, Barcelona, Hamburg and Antwerp. As there is no definite list of common air contaminants, each port can make its own. For example, in its sustainability report, the port of Antwerp considers sulphur dioxide (SO_2), nitrogen oxides (NO_x), as well as particulate matter (PM_{10}) for air pollution, whereas the port of Vancouver takes into account more gases in its landside emission inventory, such as carbon monoxide (CO), volatile organic compounds (VOCs) and ammonia (NH_3).

Shipping emissions can present a large share of the total emissions in the port-city. These can represent up to half of the emissions of the port-city, as in Hong Kong and Los Angeles/Long Beach with respect to SO_2 emissions (Table 2.10). Ports can also have considerable impacts on other aspects of air emissions of cities, such as NO_x and PM_{10}. In addition, most large port-cities are also industrial estates with their own air emissions, which are not included in the table below. However, it is not easy to collect and compare these data, because of the different focus and scope of the air emissions inventories of ports and cities. City inventories do in many cases not include the port area, do not focus on transport-related emissions or focus on GHG emissions, whereas the main air emissions impacts from ports come from SO_x, NO_x and PM.

Table 2.10. Shipping-related emissions as share of total city emissions

Port	SO_2	NO_x	PM_{10}
Hong Kong	54%	33%	n.a.
Shanghai	7%	10%	n.a.
Los Angeles/Long Beach	45%	9%	n.a.
Rotterdam	n.a.	13-25%	10-15%

Source: Authors' data compilation based on port's air emission inventories.

Among the air contaminants in ports, $PM_{2,5}$ and NO_x present higher externalities, thus being the most pressing air contaminants to measure and mitigate. In their study on 13 selected Spanish harbours, the main pollutant regarding emitted quantity is NO_x, representing 86% of total emissions of air contaminants. However, it is important to underline that the kind of ship matters. Indeed, the Vancouver 2011 emission inventory explains that container ships and cruise ships play a particular part in port-related emissions. If containership represents 26% of total port calls, it is the main source of emissions of NO_x (33.6% of total). In parallel, cruise ships represent 14% of calls but 32.5% of port-related emissions of CO_2. Air pollution from ports can present large external costs to their cities (Table 2.11). For a standard city with a population of 100 000 people, a tonne of $PM_{2,5}$ presents social costs of approximately EUR 33 000, whereas it presents social costs of EUR 495 000 for a city of several million people. The same applies to SO_2, whose costs vary from EUR 6 000/tm to EUR 90 000/tm respectively (Holland and Watkiss, 2002, cited in Castells Sanabra, Usabiaga Santamaría and Martínez De Osés, 2013).

Table 2.11. External costs of shipping emissions in selected port-cities

Port	Indicator	Estimated cost	Source
Bergen (Norway)	Air emissions of ships at berth	EUR 10-22 million	MacArthur and Osland (2011)
13 Spanish ports	$PM_{2,5}$, SO_2, NO_x emissions	EUR 206 million	Castells Sanabra et al (2013)
Piraeus (Greece)	External cost per cruise passenger	EUR 2.9-10.4	Tzannatos (2010)
Kaohsiung (Ch.Tapei)	Air emissions of ships at berth	EUR 119.2 million	Berechman & Tseng (2012)

Source: Authors' compilation based sources cited in the table.

Water quality

Ports are a source of pollution of water, but detailed information on emissions in water is scanty by comparison with air emissions. One major source of water pollution in ports is oil spills, coming from port run-off, unloading and loading of oil tankers, removal of bilge water and leakages. Oil spills result from normal activities, accidents and illegal dumping practices. Although tanker accidents are thought of as an important source of water pollution, some estimates indicate that normal shipping operations are responsible for over 70% of the oil entering the sea from marine transportation. Statistics also show that 80% of oil spills occur in harbour waters (Miola et al., 2009). Bailey et al. (2004) note that in the year 2000, 8 354 oil spills were reported in US waters, accounting for more than 1.4 million gallons of spilled oil. These spills caused up to three times as much oil contamination as tanker accidents.

The other main source of water pollution is the transfer of harmful aquatic organisms (including dormant stages of microscopic toxic aquatic organisms such as dinoflagellates, pathogens such as the bacterium *Vibrio cholera*) due to the discharge of ballast water, which is used to stabilise vessels (Miola et al., 2009). According to the International Maritime Organisation (IMO), about 10 billion tonnes of ballast water is transferred each year, amongst which 3 500 million tonnes is discharged (Endresen et al., 2004). Other sources of water pollution are pollution from slop (residual chemical products contained in the tanks and of the product used in washing operations), whether it is treated or illegally discharged, and leaching of anti-fouling paints. These paints are used to coat the bottom of ships to prevent aquatic fauna and flora attaching to the hull, slowing down the ship and increasing fuel consumption (OECD, 2011).

Soil

Soil pollution from the maritime transportation sector is mainly linked to the terrestrial activities in port areas. There are multiple sources of soil pollution in port areas: discharge of oil on the soil (from vehicles and fuel deposits), chemical spills from ship demolition; and emissions of SO_2, NO_x causing acid rain and consequently, soil acidification. However, the main impact of ports on soil is erosion. Because the presence of a port modifies the natural transport of coastal sediment, it causes erosion. This can produce a degradation of natural habitat and harm biodiversity. It can also destroy land that could be used for recreational or productive uses (Miola et al., 2009).

Waste

Port activities produce waste, especially from oil terminals, fuel deposits and dry-docks operations, which produce oily and toxic sludges. Waste also comes from other sources, such as ships (Miola et al., 2009). A crucial role is played by cruise ships; although they represent less than 1% of the global fleet, they are responsible for 25% of all waste, consisting of glass, tin, plastic, paper, cardboard, steel cans, kitchen grease, kitchen waste and food waste (Miola et al., 2009). Waste is a challenge for port authorities, which have to collect and treat it. For example in 2010, the port of Antwerp collected more than 250 tons of oil-containing and various hazardous wastes in the waste dumps of the port and nearly 400 tons of non-hazardous waste (Port of Antwerp, 2010). Plastics are an important source of waste, and plastics released from vessels makes up almost 80% of all garbage found on shorelines and on the sea floor in the Mediterranean (Abdulla and Linden, 2008). Waste is linked to health and land use issues. Indeed, as the Port of Houston notes, improving waste recycling is a way to reduce landfills.

Biodiversity

Ports' impact on biodiversity is due mainly to air emissions, waste and ballast water (Table 2.11). One of the main sources of disruption of the balance of ecosystems is the introduction of non-indigenous marine species through the transfer of ballast water. Non-native species can compete with local species and cause heavy environmental damage. Sulphur and nitrogen compounds emitted from ships, oxidising in the atmosphere, can contribute to acidification, causing acid depositions that can be detrimental to the natural environment, such as lakes, rivers, soils, fauna and flora. NO_x deposition is also a vector of eutrophication, which can alter ecosystems. Dredging may have an impact on the ecosystem, but in most dredging projects the impact is temporary and often limited through environmental monitoring and compensatory measures. Finally, noise can disturb animals both at sea and in port areas. Economic valuations of port-related biodiversity loss appear substantial. Landside impacts of ports concern mainly birds, which can breed on port land. Light from industrial activity can also be detrimental to bird populations.

Table 2.12. Port impacts on biodiversity

Source	Effects	Species affected
TBT paint	Morphological change, change in population structure	Marine invertebrates
Anchoring	Sediment re-suspension, decrease of photosynthetic ability	Marine organisms living in harbours, seagrass
Oil discharge	Genetic damage, oxidative stress, behavioural abnormalities	Marine vertebrates, birds
Gas emissions	Ocean acidification	Plankton, coral, organisms with calcification process
Chemicals	Accumulation of substances in organisms that cause disruption of the endocrine system	Predators at the top of the food chain
Waste	Eutrophication	Seagrass, fish
Debris	Death by ingesting floating plastics	Seabirds, turtles, whales
Ballast water	Introduction of invasive non-indigenous species, extinction of native species	Entire ecosystem
Noise	Problems of communication for animals, collisions	Cetaceans, marine mammals
Collisions	Death	Cetaceans, other marine vertebrates (whales, dolphins, turtles)

Source: Authors'elaboration based on Abdulla, A. and O. Linden (eds.) (2008), "Maritime Traffic Effects on Biodiversity in the Mediterranean Sea: Review of Impacts, Priority Areas and Mitigation Measures", IUCN Centre for Mediterranean Co-operation, Malaga, Spain.

Noise

Noise impact from ports can derive from ships, cranes, trucks, trains and industrial activity. These different sources can have a large impact. In Livorno, the port-related road traffic of heavy vehicles was recognised as one of the main causes of noise in urban residential areas. In terms of absolute noise emission, the industrial area predominated, but the large distance from the urban area allows the impact to decrease to negligible levels. Berthed ships represent another significant noise source; a significant contribution comes from ferries and cruise vessels, because of the proximity of the passenger terminals to the city centre (Morretta, Iacoponi and Dolinich, 2008). A ship that falls within the external noise limits for ships set by the IMO is permitted to have a diesel generator exhaust sound power of 107 dB(A). If the sound power is 107 dB(A) and the noise limit for city residential areas is 40 dB(A), as is the case in various countries such as Denmark, the ship must be berthed more than 600 metres away in order not to exceed the noise limit (Lloyd's Register ODS, 2010).[4] Not surprisingly, noise has been one of the sustainability priorities of European port authorities over the last decade, consistently ranking in the top five most important environmental impacts as perceived by European ports, according to surveys by the European Seaports Organisation (ESPO, 2013).

A significant number of urban residents can be affected by port noise. This can be illustrated by Strategic Noise Maps that characterise the port noise climate, creating an acoustic map for each source of noise, as well as a map with overall port-related noise impacts. Through cross-comparisons between characteristic sound levels of the port area and the surrounding urban areas, it is possible to establish the number of residents affected. Based on a limited number of cases for which such an exercise has been conducted, the total number of people exposed to port-related noise ranges from 240 to 900 inhabitants per port (Table 2.12). A more critical situation may result from terminal and industrial activities that run 24 hours a day; for example, the number of people exposed to a nightly sound value greater than 50 dB(A) was 900 inhabitants, whereas the daily impact was 300 inhabitants (taking into account the daytime limit of 60 dB(A) (Morretta, Iacoponi and Dolinich, 2008). The number of people exposed to noise from water traffic and ports in Finland was estimated at between 100 and 500. However, many areas with special sensitivity to noise, such as schools, hospitals and cultural centres, are not only exposed to port noise, but also to other sources of noise, such as roads and railways. This can complicate the measurements, which makes it complicated to directly assess the particular impact of the port (Rizzuto et al., 2010).[5] The main harm that noise causes to the exposed population is annoyance and sleep disturbance, because they are more sensitive to noise levels than to other harmful effects.[6] According to the WHO, sound pressure levels on the facades of living spaces should not exceed 45 dB at night, so that people can sleep with their bedroom windows open (Berglund, Lindvall and Schwela [eds], 1999).

Table 2.13. Urban residents exposed to daily port noise

Port	Number of people exposed to daily port noise > 60 dB (A)
Amsterdam	242
Livorno	300
Valencia	856

Source: NoMEPorts (2008b), *Good Practice Guide on Port Area Noise Mapping and Management; Technical Annex*, Port of Amsterdam, Netherlands.

Health impacts of ports

Negative social impacts of ports are often health-related and generated primarily by pollution (air and water) and noise. Air pollution negatively impacts society by causing various respiratory and cardiovascular diseases, while water pollution from the storm run-off of port-related activities can result in skin and neurological health problems (Human Impact Partners, 2010). A concentration of more than 0.06 mg/m3, SO_x can affect the respiratory system and trigger bronchitis episodes and chest infections. Nitrogen oxides can also provoke serious damage to the breathing apparatus at a concentration of over 100 mg/m3, and even be lethal at 300-400 mg/m3 (Quaranta et al. 2014). Particulate matter (PM) also contributes to serious health problems, such as premature mortality, asthma attacks and millions of lost days of work (Miola et al., 2009). These environmental consequences, which render living conditions unhealthy can be categorised as direct effects. Several studies cite collisions and pedestrian safety as health issues directly related to living near a port. In addition, the British Department of Transportation considers indirect health impacts such as a lack of parks, community centres and clinics, which can contribute to mentally and physically healthier populations (Department of Transport, 2011). Perceived health impacts are also important to consider, as shown by a community survey in Seattle that discovered that 34% of residents in the two port communities of Georgetown and South Park rated their health status as "poor" or "fair", while only 10.5% gave this response in King County, Washington, as a whole (Community Coalition for Environmental Justice and Puget Sound, 2010).

Most of the studies concerning the health impacts of ports on the immediate population come from the United States, with several of these studies in Los Angeles and Long Beach, and mounting efforts in Houston, Seattle, and New York/New Jersey. Los Angeles/Long Beach appears to produce the most complete data regarding the health impact of ports. Data from the Los Angeles County Health Survey reveals that Long Beach communities in close proximity to the Port of Los Angeles experience higher rates (2.9 percentage points on average) of asthma, coronary heart disease and depression, compared to other communities in Los Angeles (Human Impact Partners, 2010). Additionally, the California Air Resources Board attributed 3 700 premature deaths per year to ports and the shipment of goods (Sharma, 2006). Europe has also made significant advances in assessing negative environmental effects of port activity, while not always linking these impacts to public health literature and studies.

As for air pollution, nitrogen dioxide and organic carbon emitted from various port activities have been linked to bronchitic symptoms (Sharma, 2006). Exposure to sulphur dioxide is associated with respiratory issues and premature births. Another port source of harmful air pollutants is trucks travelling in and out of the port that produce harmful emissions that degrade air quality (UCBHIG, 2010). The Healthy Port Communities Commission has growing concerns, stating that communities surrounding the Port of Houston have the highest air toxicity rates and also elevated rates of cancer and asthma compared to Greater Houston more generally (The Citizen, 2013). Specific pollutants found in water related to adverse human health conditions include tributylin, or TBT (used to ward off barnacles and other marine organisms), oil, toxic substances, and high concentrations of heavy metals. Additionally, ballast water can carry disease-causing organisms and contaminate seafood for human consumption (Sharma, 2006). Assessment of the health impact can be conducted through measures of mortality and morbidity, using either the Value of the Statistical Life (VSL) or the Value of a Life-Year (VOLY). The monetary value of health impacts has been calculated by the Environmental Protection Agency (EPA) in the United States, for example: the lifetime cost of one case of chronic bronchitis is worth USD 420 000 in 2010 income (Miola et al., 2009).

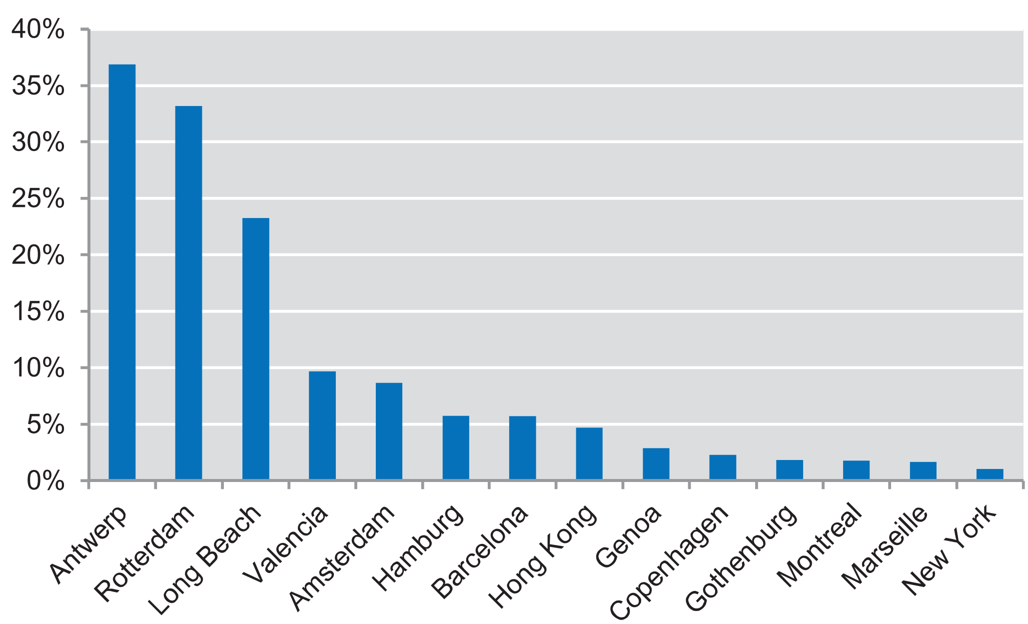
Noise from port operations can cause high blood pressure, heart disease and other stress-related symptoms. In Shanghai, for example, the population is said to suffer more from noise pollution than from air pollution caused by ports (Yang in Sharma, 2006). Children can be particularly affected by the noise generated by port activity, and delayed learning has been linked to noise in the public health literature (*ibid*). This "port noise" is caused primarily by diesel engines approaching and idling in the dock, activity that is capable of reaching between 80 and 120 dB, as well as the loading and unloading of goods (Sharma 2006; Morretta, Iacoponi and Dolinich, 2008). A study found that port-related vehicle traffic (in combination with public transport and train traffic noise, caused more than a third of residents in West Oakland, California, to be highly affected by noise, with eight myocardial infarction deaths (15% of all myocardial infarction deaths) per year attributable to this noise exposure, and one-third of residents at risk of sleep disturbance. Compared to a standard of 60 dB, the existing noise levels were said to have resulted in the possibility of a 29% impairment in recall and reading and a 4% impairment in recognition and attention, with potential consequences for the cognitive development of children in West Oakland. (UCBHIG, 2010).

Land use impacts

Another characteristic of modern ports is their space-intensity; they occupy a relatively large share of the metropolitan land surface. Among selected port-cities, Antwerp, Rotterdam and Long Beach occupy a very large proportion of urban land used for port activities (Figures 2.5 and 2.6). Other large ports tend to use a percentage of the city surface that is lower than 5%. Even a port like Hamburg, located in the very core of the city, occupies only slightly more than 5% of the land surface of the city. Caution is called for in these comparisons, because the administrative boundaries of cities vary widely but have a large impact on the outcome of these calculations. Still, comparisons are not meaningless. Land use impacts often become prevalent in case of port development projects, because they enter into competition for land with other uses of the city surface, or can degrade natural habitat and biodiversity if they occur in areas that were not previously developed, as is often the case.

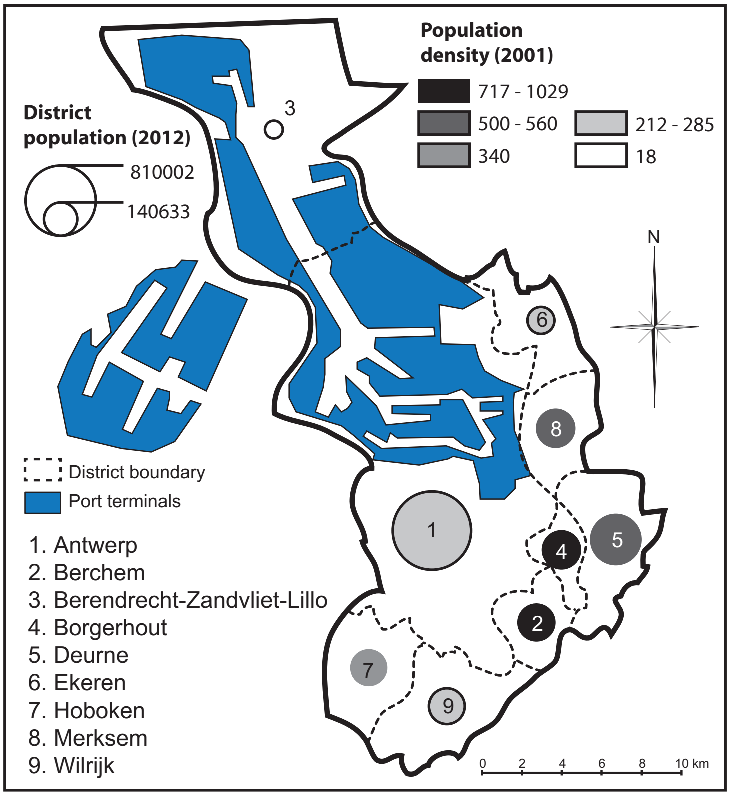
The economic consequences of port land use can also entail opportunity costs. Agglomeration effects and high job density are generally considered to be factors of urban economic growth, and these agglomeration effects may be constrained by the presence of large port areas. Since they are generally not easily accessible to the public, they cannot be expected to generate the agglomeration effects associated with urban areas in terms of knowledge spillovers, although clustering effects in port areas could be dependent on size.

Figure 2.5. Port land surface in selected port-cities (as share of total city area)



Source: Authors' data collection based on data provided by port authorities; Civic Exchange (2009), "Green Harbours II: Reducing Marine and Port-related Emissions in the Pearl River Delta Region", Civic Exchange, Hong Kong; Hong, Z., et al. (2013), "The Competitiveness of Global Port-Cities: The Case of Shanghai, China", *OECD Regional Development Working Papers*, No. 2013/23, OECD Publishing, Paris, http://dx.doi.org/10.1787/5k3wd3bnz7tb-en; Merk, O. (2013), "The Competitiveness of Global Port-Cities: Synthesis Report", *OECD Regional Development Working Papers*, No. 2013/13, OECD Publishing, Paris, http://dx.doi/10.1787/5k40hdhp6t8s-en; Starcrest Consulting (2011), "Port of Los Angeles inventory of air emissions – 2010", *Technical Report,* ADP#050520-525.

Figure 2.6. Land surface of the Port and the City of Antwerp



Traffic impacts

The presence of a port can lead to urban congestion caused by the hinterland traffic to and from the port area. A large share of freight transport between a port and its hinterland is by truck, which adds to road traffic volumes, and often to congestion costs in metropolitan areas that are struggling with congestion. For example, the costs of road congestion due to a 6% rise in freight volumes in the Port of New York/New Jersey have been estimated at between USD 0.3 billion and USD 0.8 billion per year (Berechman, 2009). Rotterdam and Antwerp provide relevant examples of port-cities that have experienced greater congestion due to the growth of port activity (Borger and Bruyne, 2011). The issue is even more pronounced in developing countries and emerging port-cities. Congestion in urban areas attributable to port activity and traffic heightens the negative economic and environmental impacts of the global shipping trade on metropolitan regions hosting port facilities. Such challenges require innovative policies to promote sustainable port activities and efficient transport between the port and the hinterland.

Urban congestion due to port-related traffic originates at the port-land interface. While containerised cargoes were, in part, made to facilitate intermodal movement between port and hinterland, urban areas are not unaffected by large shipments and movements of goods. Inadequate port services and cargo handling equipment, availability of storage space, excessive turn-around times and unloading time can all contribute to delays in urban traffic flows (Jaja, 2011). Furthermore, high truck volumes and their large cargoes contribute disproportionately to traffic accidents and ensuing delays (Giuliano and O'Brien, 2008).

Congestion on urban road networks due to increased cargo throughput at a port can, in turn, negatively impact the port. It is widely acknowledged that port activities and transport network operations cannot function independently of each other. The inefficiency of either one will forcibly negatively impact the other, which indicates how tightly inland networks and seaports are connected (Notteboom and Rodrigue, 2008). In US port-cities, intensified port competition can result from such congestion, as clogged networks tend to correlate to a shift from shipping companies to a neighbouring and often rival port (Wan et al., 2013).

Other negative impacts of ports

Ports also have other impacts that can be a source of nuisance to local citizens. These include:

- **Visual impacts**: First, industrial activities, of ports, with bulk cargo piles and stacks of ugly materials may give an unpleasant impression (Economic and Social Commission for Asia and the Pacific, 1992). Then, particles and NO_2 linked to air emissions from maritime transport activities, as highlighted by Holland et al. (2005), can have impacts on visibility, by reducing the visual range (Miola et al., 2009). The last issue in relation to the visual impact of ports concerns artificial lights burning 24 hours a day. Lighting may cause a nuisance to nearby residents and also have negative effects on wildlife, including disorientation and a confusion of biological rhythms. Lighting can cause mortality among bird populations, because they are attracted to brightly lit buildings, and circle these structures until they die of exhaustion or run head into them (Bailey et al., 2004).

- **Odour**: Diverse port activities can provoke unpleasant smells that can harm local residents' quality of life. The port of Antwerp, in its sustainability report, notes that if the petrochemical industry appears to be the largest source of environmental damage in the port area, the majority of the complaints involve complaints about odours. It thus appears that a discrepancy exists between the concerns of port authorities and what local residents consider the most important negative impacts, because odours are not part of the top concerns of port authorities (ESPO, 2013).

- **Dust**: This is produced in ports mainly by bulk cargo handling and storage, construction work and road traffic. It is measured by suspended particulate matter (Economic and Social Commission for Asia and the Pacific, 1992). Particles can penetrate the human respiratory tract and exacerbate respiratory conditions such as asthma (Fortescue, 2011).

- **Social impacts**: These include all the impacts of the development of ports that could influence the life of local communities, such as relocation of villages, disruption of lifestyle, formation of slums, etc. Indeed, modernisation brought by the development of ports can change the cultural traditions and the everyday life of the local community, for example by disturbing the local fishery operations, as well as increasing the risk of accidents, which is of concern for local populations (Economic and Social Commission for Asia and the Pacific, 1992). Furthermore, oil and wastes discharged from ships can reach beaches and disturb recreational activities, as well as tourism.

- **Security issues**: Ports are often associated with military installations, nuclear power plants, oil refineries, fuel tanks, pipelines, chemical plants and major cities with dense populations. First, transport of hazardous goods poses risks of explosions. For example, in November 2002, an explosion involving improperly stored fireworks and calcium hypochlorite containers (a bleaching agent used in swimming pools) caused one death and extensive damage to the 4 389 TEU *Hanjin Pennsylvania* and its cargo off Sri Lanka (OECD, 2003). Furthermore, ports are crucial places for international contraband; as Monson Jessup and Casavant (2006) note, 12 seaports surveyed by the United States Interagency Commission on Crime and Security in American Seaports accounted for 69%, 55% and 12% respectively for all cocaine, marijuana and heroin seized nationwide (by weight). The use of containers for illegal purposes is facilitated because it is impossible to inspect all containers. In the United States, only 4% to 6% of containers' content is verified (Monson, Jessup and Casavant, 2006). It is noteworthy to underline a dramatic shift after the September 11, 2001 terrorist attacks: security concerns shifted to assessing threats of possible terrorist attacks, through the smuggling of weapons of mass destruction shipped into a country and detonated at a port, using containers for transport or even an entire ship as a weapon.

Although this does not constitute an impact of ports on their environment, seaports are particularly vulnerable to climate change impacts, because of their location in coastal zones, low-lying areas and deltas. They can be particularly affected by rising sea levels, floods, storm surges and strong winds. Climate change is expected to have a range of diverse environmental, social and economic effects. In its Fourth Assessment Report, published in 2007, the Intergovernmental Panel on Climate Change (IPCC) estimated that global average sea level would rise from 18 centimetres to 59 centimetres by the last decade of the 21st century (US EPA, 2008). One recent study has estimated that assuming a sea-level rise of 0.5 metres by 2050, the value of exposed assets in 136 port megacities may be as high as USD 28 trillion (Lenton, Footitt and Dlugolecki, 2009). Ports will also have to consider anticipated sea levels not only for economic reasons, but also to prevent leaching of contaminants. The severity of these impacts will vary widely by geographical location and depend on a number of factors, and uncertainty over their exact magnitude makes it difficult to implement adaptation measures.

Where do the negative impacts take place?

Port impacts have generally become suburbanised. Many port sites have relocated from city centres. Port relocations and gradual spatial disintegration of ports and cities over time have taken place in many countries and have had a profound influence on ports. Remaining port functions near highly populated areas have been constrained because of public resistance to their negative impact. However, there is a large variety between port-cities. Because ports are capital intensive, port relocations are often not immediately possible and the shift has often been gradual, through new terminal development away from city development. Several ports have thus developed on multiple sites, which adds a new layer of complexity to evaluating the positive and negative impact. Port layout also is important, because the boundary of the port area and a city is the location of most environmental impacts. If this boundary abuts on a large concentration of population, the intensity of port impacts will evidently be larger. Finally, the governance component to this discussion, where most of these impacts affect surrounding municipalities, often calls for a metropolitan or regional approach.

The effects of pollution, dust and noise are all very localised, and most of the congestion costs occur close to the ports. Other regions are also subject to the negative impacts of the hinterland transport of port cargo to or from their region, but these effects are more diluted than the impacts in the port-city. Moreover, the negative impacts are skewed; large port-cities can be considered environmental hotspots. According to our estimates, the largest 25 ports in the world account for around half of the shipping emissions in all the world's ports (Merk, 2012), implying a large difference in negative port-city impacts depending on port size. Other environmental impacts from shipping are evidently global, and many take place at sea, but these become particularly evident in port-cities.

Weighing ports' benefits against their negative impacts

The overview of impacts presented in this chapter shows that ports' costs and negative effects are localised, whereas benefits are usually generated at the supra-regional (national) and even supranational level (Table 2.13). This finding is in line with the mismatch suggested by various authors (*e.g.* Hesse, 2006). There are substantial benefits from ports, but they can have considerable leakages to other regions. These spillovers include lower costs of external trade and indirect economic linkages, including supplier linkages and economic specialisations that spill over to other regions. Maritime-related engineering services are to a limited extent located in Rotterdam, for example, but to a much larger extent in the Rotterdam metropolitan region and the rest of the Netherlands (Merk and Notteboom, 2013). Port-related employment is increasingly de-concentrating, in many cases away from port regions. The port can be a revenue source for local governments if they are in charge of the ports, but in many cases, the national government receives the net profits. Ports can provide interesting sites of renewable energy production, and in particular biomass production, considering the large diversity of commodity flows and sophisticated refinery infrastructure, but this production capacity will most likely serve a wider area than just the port region. These spillovers are not problematic from a national or supra-national perspective – and might in fact be desirable considering the gateway role that ports play for their countries – but pose particular challenges for port-cities and their mayors that would like to use the port as an engine for an urban economy.

All the more since most of the negative effects of ports are localised, including the environmental effects identified in this chapter. The impacts of hinterland traffic are also mostly local, because most of the short-range hinterland traffic is by truck (and in many cases more polluting), whereas most of the longer-range hinterland traffic is by modes with less negative externalities (rail and barge). Comprehensive evaluation of this mismatch is difficult to quantify, in particular due to difficulties in measuring negative impacts. However, various studies have been conducted in recent decades to quantify negative impacts (Box 2.1).

Table 2.14. Costs and benefits of global ports

	Local	National	Supra-national
Costs			
- Economic	Infrastructure investments Opportunity costs, land use	Infrastructure investments	
- Environmental	Air, water, waste, noise, odour Hinterland traffic		
Benefits			
- Economic	Port-related value added Agglomeration effects Knowledge spill-overs Lower costs of trade	Forward/backward linkages Lower costs of trade	Lower costs of trade
- Environmental		Renewable energy production	

Box 2.1. Methodologies to measure negative port impacts

One of the emerging approaches for economic appraisals of the port-city relationship – in particular the impacts on city population – is the contingent valuation method, based on an analysis of the local population's willingness to pay for certain policies or to avoid certain proposed measures (Saz-Salazar, García-Menéndez and Merk, 2013). Such studies include one on the renewal of vacant port areas for recreation purposes in the Spanish port-city of Castellón (Saz-Salazar and García-Menéndez, 2003), and one assessing negative externalities resulting from port expansion in Valencia (Saz-Salazar, García-Menéndez, Feo-Valero, 2012). The Valencia study calculated that the average compensation required would be around EUR 100 per family negatively affected, amounting to a present value of the costs borne by local citizens of approximately EUR 41 million. A more or less comparable study of Tianjin (China) showed that citizens had no statistically significant preference for or disapproval of port construction (Zhai and Suzuki, 2008). Another approach for quantifying port impacts is the hedonic price analysis, measuring the effect of different economic parameters on the cost of housing.

Hedonic price analysis studies have found that proximity to industrial zones has negative price effects, but this is not necessarily true for port areas.[7] Proximity to an industrial site exhibits a statistically significant negative effect on the value of residential properties in the Randstad region (Netherlands), but the effect of closeness to a port area was found to be insignificant (De Vor and De Groot, 2010). Hedonic price analysis conducted in Saint-Nazaire (France) showed no linear and univocal relation between proximity to the port industrial zone and housing prices, which could possibly be explained by a positive effect of proximity to place of work or easy access to the transport network, which can offset air pollution or environmental risks (Maslianskaia-Pautrel, 2009). Similarly, close proximity of housing to a seaport was found to have an insignificant effect on individual well-being in Ireland (Brereton, Clinch and Ferreira, 2008). Some evidence suggests proximity to the port-industrial complex of Port Jérôme, which is part of the Rouen port cluster, has negative effects on house prices. Hedonic price analysis, taking into account a house's intrinsic characteristics, shows that close proximity to this port-industrial complex leads to a price discount of approximately 12% of the average price for a similar house. Proximity to the River Seine leads to an even larger reduction, namely 38%; the Seine is thus not considered an asset in this regard (Travers et al., 2009). The lack of a broad base of quantitative assessments makes it difficult to generalise about the extent of the port-city mismatch of benefits and negative impacts; much is unknown and much depends on local circumstances.

Another negative port impact relates to the external costs of hinterland traffic, including costs related to congestion, accidents, air pollution, noise and other external costs. Haezendonck, Dooms and Coeck (2006) calculated the external costs of hinterland traffic related to the port of Rotterdam to be around EUR 240 million in 2000. Even if these calculations are dependent on the data quality and underlying assumptions, a growing academic literature supports such results (Maibach et al., 2008).

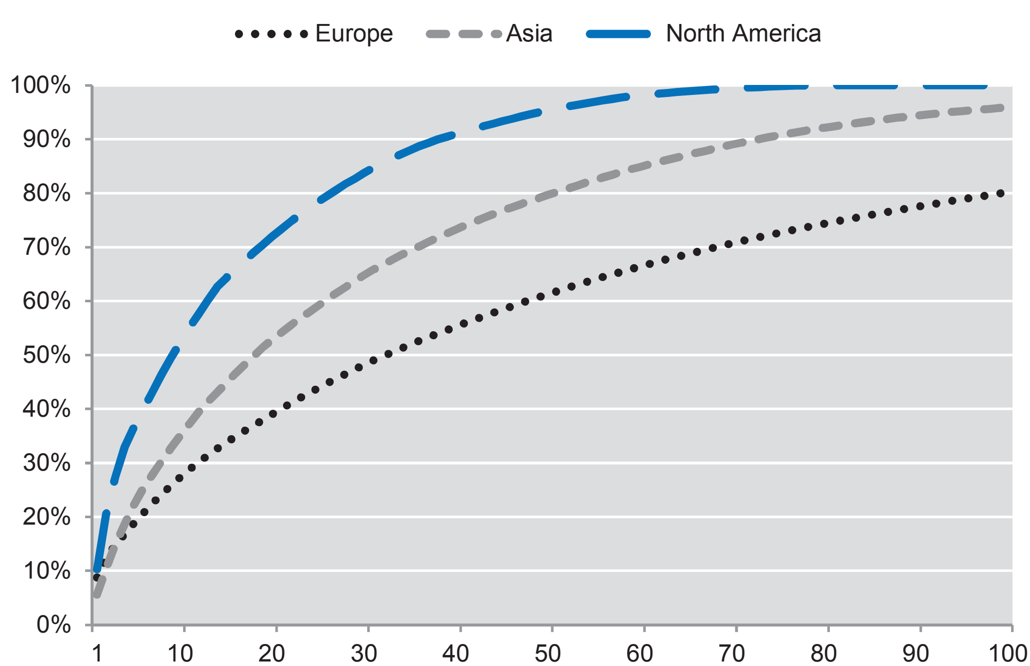
Source: Zhai and Suzuki, 2008; De Vor and De Groot, 2010; Maslianskaia-Pautrel, 2009; Brereton, Clinch and Ferreira, 2008; Travers et al., 2009; Haezendonck, Dooms and Coeck, 2006; Maibach et al., 2008.

The nature of the port-city interface, however, does have an effect. This can be illustrated by the distinct perspectives for Rotterdam and Amsterdam, the largest and fourth-largest European seaports, both located in the Netherlands. In spatial terms, port functions and urban functions have become increasingly dissociated in Rotterdam. The newest and most active port terminals are now situated at more than 40 kilometres from the city centre, and part of port activities take place in inland terminals (at extended gates such as Moerdijk). In Amsterdam, port functions have retreated to some extent, but a significant part of the port activity still takes place relatively close to the city centre. As a result, the port-city challenges are different. In Rotterdam, the congestion and environmental impacts of the port-industrial cluster can be felt in the city, but most of the port jobs are now held by workers from outside the city and the connection of urban citizens and businesses to the port complex is becoming attenuated. In Amsterdam, there is strong pressure to convert parts of the port premises to other urban functions, such as housing and office development (Merk and Notteboom, 2013).

Emerging trends that influence port impacts

Several developments have increased the port-city mismatch of benefits and impacts in recent decades. Containerisation has led to a standardisation of cargo handling, requiring less local labour. Growing ship sizes resulted in port concentration and the emergence of hub-and-spoke port networks. The top ten North American ports in 2009 handled half of the total port volume on their continent whereas the share was 35% for Asian ports and 27% for European ports (Figure 2.7). The concentration among container ports has increased in recent decades, as indicated by the increasing scores on the Gini coefficients among ports in Europe, NAFTA and Asia. Analysis of the most dominant relationships of each port with other ports, based on a dataset of vessel movements, shows that ports are indeed subject to hub and spoke tendencies, and that a limited number of ports, such as Singapore and Hong Kong, act as a central node for many other ports.

Figure 2.7. Port concentration in Europe, North America and Asia (2009)



Note: Horizontal axis indicates the top 100 ports; the vertical axis indicates the cumulative traffic share of the first port to the first 100 ports.

Source: Authors' elaborations based on data from *Journal de la Marine Marchande,* editions from 1970 to 2013.

As a result, port functions in several cities declined or stagnated. Logistics activities moved out of port regions to places with more available land, spreading out port-related employment. Large ports expanded their hinterlands towards new regions, reducing their dependence on the port-city. Consolidation and globalisation of the shipping and port terminal industry changed port authorities' influence. Terminal operations used to be a public or local activity, but in recent decades, global terminal operators have massively expanded, often at the cost of local operators, and are now present in all large world ports. Operators with fewer local connections are less inclined to take into account the benefits or impacts on local communities. Global carriers have emerged as important players with huge market power that are able to shift almost instantaneously from one port to another. This has had considerable consequences for local ports, since some of the large carriers can represent up to a quarter of local port traffic (Table 2.14). Moreover, these carriers have been able to transfer the costs of increased vessel sizes, such as dredging and hinterland infrastructure, to public authorities.

Table 2.15. Port use shifts by global carriers

From	To	Volume TEUs	Date	Carrier
Singapore	Tanjung Telepas	1 000 000	2005	Maersk
Gioia Tauro	Port Said and Malta Freeport	700 000	2011	Maersk
Algeciras	Tanger-Med	500 000	2010	Maersk
Ningbo	Busan	400 000	2007	MSC
Tacoma	Seattle	180 000	2009	Maersk
Barcelona	Tercat	130 000	2009	Evergreen
Tercat	Barcelona	120 000	2009	Maersk
Barcelona	Tarragona	70 000	2009	ZIM
Seattle	Tacoma	n.a.	2012	Grand Alliance
Auckland	Tauranga	n.a.	2011	Maersk
Manzanillo	Lazaro Cardenas	n.a.	2004	Maersk
Valencia	Barcelona	n.a.	2007	China Shipping
JNP	Mundra	n.a.	2011	Hapag Lloyd

Source: Own data collection based on articles in *Port Strategy* magazine.

These developments are expected to continue. The average size of a container vessel has doubled in the last decade from an average capacity of 2 000 20-foot equivalent units (TEU) in 2000 to more than 4 000 TEU in 2010, a trend that is continuing with as a current wave of new vessels up to 18 000 TEU come into operation. This will no doubt reinforce the process of port concentration. A process of port regionalisation is under way in several countries, which will arguably further distribute the employment and value added related to port activity. Emerging markets are attracting the interest of global port terminal operators, which could reduce the local affiliations of ports in these countries.

The implications of these developments are increasing pressure on port-cities to show that ports can continue to be an asset for urban development. With economic benefits spilling over to other regions and negative impacts highly localised and concentrated, in line with port concentration, port-cities will be increasingly confronted by existential questions eroding their local support and “license to operate”. Port-cities must find ways to address such imbalances. How can they ensure that the port creates value for the city and that negative impacts are mitigated? How can they formulate a new balance of benefits and impacts? These questions will be discussed in the next chapter.

Notes

1. For example, the Bremen weighing rule states that the value added created by one ton of general cargo (conventional cargo, RORO and containers) equals the value added of three metric tons of dry bulk and 12 tons of liquid bulk. The Dupuydauby Rule attributes the following co-efficients to the different traffic categories: 12 to crude oil, 9 to liquid bulk, 6 to dry bulk, 3 to containers and RORO and 1 to conventional cargo. The Range Rules uses the following co-efficients: 1 for RORO; 1 for conventional cargo; 3 for containers; 5 for dry bulk; 2 for liquid bulk; and 18 for crude oil. See Haezendonck, Coeck, Verbeke, 2000.

2. Excluding the industries that are port required.

3. Air emissions can be divided into two groups: Common air contaminants (CACs) and greenhouse gases (GHGs). Each of these groups covers various gases. The main CACs are oxides of nitrogen (NO_x), oxides of sulphur (SO_x) and particulate matter (PM), among others. GHGs are gases present in the Earth's atmosphere that reduce the loss of heat into space (Starcrest Consulting, 2011). The main GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). GHGs affect climate as they concentrate in the Earth's atmosphere and trap heat by blocking some of the long-wave energy normally radiated back into space. Common air contaminants have a local or regional impact on air quality, whereas GHG pollutants have global impact on climate. Considering other types of air emissions, Schreier et al. (2006), underline that particle emissions from ships change the physical properties of low clouds, for the so-called indirect aerosol-effect. Particles and their precursors from ship emissions are able to act as cloud condensation nuclei (CCN) in the water vapour saturated environment of the maritime cloud (Miola et al., 2009).

4. Ship noises come from the diesel generator engine exhaust, the ventilation inlets and outlets, and secondary noise sources, such as pumps and reefers. The diesel generator is used to generate power on board of the vessel, and presents often the most predominant source of noise radiating from the ship to the surroundings. The diesel engine exhaust is often placed at the top of a funnel, which has a significant height compared to the surrounding landscape. This means that if the noise is not dampened, it may easily cause high noise levels in surroundings areas, even at large distances. The sound power in a selection of ship engines was found to vary between 135 dB(A) to 142 dB(A); and of the ventilation fans between 81 to 110 dB (A). Large hold ventilation fans are mainly used on RORO ships for ventilating car decks. Noise measurements of secondary noise sources such as reefers (cooling containers) show that the sound power of a single reefer is in the range of 90 dB(A). Each time the number of reefers is doubled, the sound volume increases by 3 dB. In general, the sound power of ships increases with the size of ships (as expressed in dead weight tonnes) (Lloyd's Register ODS, 2010).

5. With exposure limit above 55 dB.

6. EU Directive 2002/49/EC, Art.2, letter (r).

7 Hedonic prices are the implicit prices of attributes, which are revealed to economic agents from observed prices of differentiated products and the specific characteristics associated with them. This helps to explain house prices in terms of the house's characteristics, such as the type of dwelling, age, floor area, neighbourhood and job accessibility. It can also explain the impact of undesirable facilities on house values due to perceived disamenities. Such concerns (for example, worries about air pollution, health risks and public image) can manifest themselves in property markets, as buyers are likely to pay more to reside in locations farther from perceived disamenities.

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