# UNIVERSITÀ DI GENOVA

PhD MARINE SCIENCES AND TECHNOLOGIES - LOGISTIC AND TRANSPORT

# Peripherality, Dependency and Vulnerability: A Multi-scalar Analysis of the Maritime Container Transport Sector in the Era of Shocks

**Fabio Cremaschini**

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Supervisor Claudio Ferrari
Coordinator Claudio Ferrari

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# Abstract

Maritime transport is a fundamental component of the global economy and plays a crucial role in sustaining international trade and global value chains. In recent years, however, a sequence of exogenous shocks, including the Covid-19 pandemic, the blockage of the Suez Canal, the Red Sea crisis and the recent disruption scenario involving the Strait of Hormuz, has exposed the structural vulnerability of maritime transport networks. This thesis investigates the vulnerability of the maritime container transport sector through the concepts of peripherality and dependency, adopting a multi-scalar perspective that combines local, regional and global levels of analysis.

The research is structured around three empirical case studies. The first analyses the impact of the Red Sea crisis on the Italian container port system, focusing on changes in port calls, deployed capacity, container throughput, maritime services, vessel size and carrier strategies. The results show that the crisis did not affect Italian ports uniformly. While several ports experienced reductions in calls and extra-regional services, others strengthened their relative position through intra-Mediterranean and Gibraltar-related connections. The analysis highlights the differentiated resilience of Italian ports and the role of carrier strategies in reshaping port competitiveness.

The second case study examines hub dependency in the Mediterranean container shipping network between 2000 and 2023, with particular attention to Italian ports. Using maritime network analysis, the chapter shows a progressive consolidation of a hierarchical hub-and-spoke structure in the Mediterranean. Hub functions have become increasingly concentrated in a limited number of ports, while several gateway ports display declining centrality and increasing reliance on hub-mediated connections. The findings demonstrate that hub dependency is closely associated with network peripherality and represents a structural source of vulnerability.

The third case study extends the analysis to the global scale by examining uneven maritime connectivity among countries within the global liner shipping network. Through network indicators, Principal Component Analysis and k-means clustering, the research identifies different country profiles according to service diversity, operator presence, cargo capacity and transhipment dependence. The Hormuz disruption scenario further demonstrates that vulnerability is shaped not only by geographical exposure to chokepoints, but also by the structural position of countries within liner shipping networks.

Overall, the thesis argues that vulnerability in maritime container transport is also a result of the hierarchical organisation of liner shipping networks. Peripherality and dependency emerge as key dimensions for understanding how shocks produce uneven impacts across ports, regions and countries. The findings contribute to maritime transport geography, port studies and network vulnerability research, while also offering policy-relevant insights for improving the resilience and diversification of maritime connectivity.

**Keywords: Maritime container transport, Vulnerability, Hub dependency, Peripherality, Uneven maritime connectivity, Red Sea Crisis, Mediterranean, Global Maritime Network**

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# 1. Introduction

Maritime transport is the backbone of global trade: more than 80 per cent of goods are transported by sea for at least part of their journey. This well-known statement, published in one of the major reports of the United Nations Conference on Trade and Development (UNCTAD), is frequently used as an opening remark in numerous studies on maritime transport. Its success lies in the fact that it effectively captures the structural importance of maritime transport for the functioning of the global economy.

Throughout history, maritime transport has always represented a fundamental component of global economies. Authors such as Fernand Braudel (1984), in his conceptualisation of world-economies, and, later Arrighi (1994) identify the gravitational centres of the global economy as being centred on nodal maritime cities: first Venice, then Amsterdam, followed by London and, finally, New York. This shift is also described by Stopford (2009) through what he defines as the "West-line" of key maritime transport cities, extending to Shanghai in the present day.

However, with the process of globalisation that began in the 1990s, the development of global value chains (Gereffi and Korzeniewicz, 1994), and China's accession to the WTO in 2001, the volume of goods transported by sea and the degree of global interconnection reached unprecedented levels (UNCTAD, 2022).

Since then, this expansion of maritime transport has unfolded within a context of relative stability, shaped primarily by endogenous processes of technological development in shipping, such as vessel gigantism, and by market reorganisation through horizontal integration among maritime operators and vertical integration between terminal operators and shipping companies. It has also been influenced by major infrastructure projects, such as the expansion of the Panama and Suez Canals.

Since 2020, however, this relative stability has been affected by shocks of various kinds, which have brought renewed attention to the vulnerability of maritime transport and to its structural importance for the functioning of international trade.

In fact, the global financial crisis of 2008 had already produced repercussions for maritime transport. One example was the bankruptcy of Hanjin, mainly caused by the slowdown in global transport demand and by the sector's structural overcapacity (Song et al., 2019). However, this failure concerned a single operator and had consequences primarily for market restructuring, without producing structural changes in the functioning of transport chains.

By contrast, the recent and increasingly frequent exogenous crises have had a global impact, affecting all maritime operators and reshaping the geography of global maritime routes.

The first of these crises began in 2020 and was caused by the Covid-19 pandemic. Following health-containment measures adopted in several key ports within the maritime network, global maritime services experienced severe slowdowns as a result of congestion in these highly central ports. This partly revealed the highly hierarchical structure of global maritime service networks, as well as their vulnerability when major central nodes are disrupted, with effects spreading across the entire network. Moreover, this crisis also showed how the strong concentration of the carrier market, especially in the container sector, and the strategic decisions taken by operators and shipping alliances, produced uneven impacts across countries in terms of reduced transport capacity, service frequency, and transport costs (European Commission, 2023).

The other major shocks were more closely related to the geography of maritime transport and to its vulnerability with respect to what have been defined as the choke points of global maritime transport. The first recent episode that brought this issue to the fore was the six-day blockage of the Suez Canal in March 2021, when the Ever Given, a vessel of more than 20,000 TEU, ran aground in the canal, blocking one of the most important global maritime routes. Due to its short duration, however, this episode did not reach the scale of subsequent crises.

A crisis of undoubtedly greater impact was, and at the time of writing this thesis partly continues to be, the Red Sea crisis. It began when, in response to the Israeli army's military invasion of Gaza, the Yemeni Houthi group, which controls the western part of the country, repeatedly targeted commercial vessels transiting through the Bab el-Mandeb Strait, effectively making passage through it unviable. This forced shipping companies to divert the important trade route between Europe and the Far East away from the Red Sea and towards the Cape of Good Hope, circumnavigating Africa and adding approximately 4,500 nautical miles to the Rotterdam-Shanghai route.

Also geopolitical in nature is the recent crisis linked to the closure of the Strait of Hormuz by the Iranian authorities following the American military intervention in early March 2026. This blockade has had a particularly significant impact on the maritime transport of liquid bulk energy products, such as oil and gas, but it also has potential implications for the container sector, given the presence of major hub ports such as Jebel Ali in the United Arab Emirates.

This series of crises of different kinds has brought to light several dimensions of vulnerability affecting both the maritime transport network and the ports connected to it, and consequently coastal countries.

This thesis focuses on container maritime transport and analyses its vulnerability through two core concepts: peripherality and dependency. Both concepts shed light on intrinsic features of the structure of global container shipping services.

The first concept, peripherality, derives on the one hand from the highly hierarchical and polarised structure of the global maritime network, which is mainly based on a hub-and-spoke organisation. This system is characterised by a limited number of highly central ports connected through intercontinental services, and by lower-ranking, more peripheral ports served primarily by regional services. The former concentrate large volumes of cargo, while the latter tend to attract smaller cargo volumes and are penalised by multiple transhipment chains in order to reach the rest of the port network. On the other hand, peripherality is also linked to geographical conditions, primarily the distance from the main maritime routes. As will be shown, this condition may vary over time and be influenced by different shocks.

The concept of dependency is addressed in this thesis through two distinct dimensions. The first is hub dependency, namely the extent to which a port is forced to rely on hub ports and feeder services in order to access the rest of the network. The second is the dependency of a port or country on a limited number of operators for its maritime transport services. Highly dependent ports and countries can rely on fewer alternatives for their international maritime connections, and therefore possess lower levels of "redundancy", making them more vulnerable to external strategic decisions or logistical disruptions.

Methodologically, the thesis draws on different types of data sources, including port calls, information from Lloyd's List, and liner service rotations published by carriers. The use of these diverse datasets makes it possible to analyse the global maritime network as well as local changes affecting individual ports, across different spatial scales and levels of detail. The thesis also adopts a broad methodological framework, combining granular empirical analysis, shift-share analysis, measures from complex network analysis, and k-means clustering based on PCA components. Together, these data sources and methods provide a comprehensive set of tools for examining the vulnerability of maritime transport from multiple perspectives.

This thesis examines these two concepts from three different perspectives and at three distinct geographical scales. The manuscript is divided into three different chapters, which illustrate three different case studies: The effects of the Red Sea crisis on the Italian container port system in the short to medium term, the hub dependency in Mediterranean Sea between 2000 and 2023, and the Uneven maritime connectivity in the Global Liner Shipping Network and the Hormuz crisis impact.

The first operates at the local/national scale, focusing on Italian ports and using carrier strategies and flow performance as interpretative lenses for analysing competitiveness and resilience. The second operates at the regional scale, focusing on Mediterranean ports and the evolution of the hub-and-spoke model in the region, using levels of hub dependency and connectivity measures as interpretative tools. The third operates at the global scale, focusing on countries and interpreting their position through the structure of their liner shipping services and their distance, in terms of transhipment, from all other countries.

The multi-scalar approach across different geographical scales provides an overview of maritime transport and the dynamics of vulnerability and dependence from various perspectives. This approach makes it possible to examine not only how the structure of global maritime transport and the strategies of shipping companies influence connectivity and performance at port level, but also how these dynamics display different characteristics and potential effects at country level and on a global scale.

Chapter 1 focuses on the ten largest Italian container ports, which together account for the great majority of national container traffic, and analyses how the disruption of the Suez-Red Sea corridor affected port connectivity, service structures, carrier strategies and competitive dynamics. The granular and empirical analysis is based on a dataset of port calls covering the period from the fourth quarter of 2022 to the fourth quarter of 2024. The dataset includes information on vessel calls, vessel capacity in TEU, operators, maritime services, port dwell time and route classification and is implemented with the data of the real cargo flows in TEU.

This chapter aims to answer the following research questions: Have Italian ports been equally affected by the RSC, and which ports have proved to be the most competitive? Has the RSC led to the marginalisation of Italian ports? Has the RSC influenced the behaviour of carriers and alliances with regard to Italian ports?

The purpose of the analysis was to understand the short-term response of the entire national port system in a Mediterranean country such as Italy. This was achieved by examining both variations in performance in terms of container flows and port calls, and changes in the structure of maritime transport in terms of shipping companies' services and commercial strategies.

The methodology combines several complementary approaches. First, the chapter compares changes in port calls, deployed capacity, container throughput and vessel dwell time before and after the onset of the crisis. Port calls and TEU are used to estimate the global performance of the ports. Second, maritime services are classified according to their route structure, distinguishing between services previously transiting through Suez, services connected to the Gibraltar route group and intra-Mediterranean services. This allows the analysis to separate the direct effects of the Red Sea disruption from broader changes in Mediterranean connectivity. Third, the chapter applies a shift-share analysis to assess changes in port competitiveness, distinguishing between traffic growth attributable to overall market dynamics and traffic changes resulting from shifts in the competitive position of individual ports. Finally, the chapter examines carrier and alliance strategies, with particular attention to changes in service frequency, vessel size, deployed capacity and the number of operators active in each port.

The chapter shows that the Red Sea crisis did not produce a homogeneous decline of the Italian port system, The impact was geographically uneven. Tyrrhenian ports generally recorded stronger traffic growth, with the exception of Livorno, while Adriatic ports were more negatively affected. Moreover, while several ports experienced a reduction in services linked to the Suez route, others benefited from the strengthening of intra-Mediterranean or Gibraltar-related connections. The reduction in port calls was often accompanied by an increase in the amount of cargo handled per call, suggesting a concentration of volumes on fewer vessel calls and greater operational pressure on terminals.

The service analysis provides further evidence of marginalisation on extra-regional routes. Most Italian ports experienced a reduction in services connected to the Suez route group, while intra-Mediterranean services became increasingly important for ports that gained market share. This represents a key finding: Ports that strengthened their intra-Mediterranean or Gibraltar-related services were better positioned to absorb the disruption. Gioia Tauro is the clearest example, as it increased both intra-Mediterranean and Gibraltar-related services, benefiting from the reorganisation of flows around the Cape of Good Hope. Conversely, ports losing regional services were generally associated with negative shift-share results. The crisis reduced the role of many Italian ports on extra-regional routes linked to Suez, while reinforcing intra-Mediterranean connectivity and transhipment functions.

Chapter 2 investigates hub dependency in the Mediterranean maritime network, focusing on the structural position of Italian ports. Whereas Chapter 1 analyses the short-term effects of an external shock, Chapter 2 examines the longer-term organisation of maritime connectivity and the extent to which Italian ports depend on Mediterranean hubs to access the wider maritime network. The analysis focuses on the 14 leading Italian container ports by TEU traffic and covers the period 2000-2023. The empirical base consists of Lloyd's List data, which provide information on ship movements, port calls, vessel identification and ship size in deadweight tonnes. These data are used to reconstruct the evolution of maritime connections among Mediterranean and global ports.

This chapter address the topic of hub dependency and the structure of hub ports in the Mediterranean by responding to the following research questions: Has the development of hub ports in the Mediterranean reduced the centrality of Italian gateway ports? Which ports have become more dependent on hub ports, and which have maintained greater autonomy? Has the development of hub ports in Mediterranean affected the vulnerability of the maritime network of Italian ports? Is there any evidence from the recent crisis?

The answers to these questions help us to understand how changes in the structure of containerised maritime transport in the Mediterranean have affected the dynamics of dependency among smaller ports, and what the consequences of these dynamics are in the event of a crisis or a disruption to the service.

The methodology is based on maritime network analysis. The chapter reconstructs the network using both Space-L and Space-P approaches. This second representation is particularly relevant for liner shipping, since ports included in the same service rotation may be commercially connected even when they are not consecutive calls. On this basis, the chapter calculates several centrality indicators, including node degree, closeness centrality, betweenness centrality and eigenvector centrality. These measures are used to assess the position of Italian ports within the Mediterranean and global maritime networks, identify trends in peripheralisation, and evaluate the role of major hubs as intermediary nodes.

The chapter develops a specific analysis of hub dependency. This approach makes it possible to capture the extent to which Italian ports rely on hub-mediated connections rather than direct access to the wider network. In addition, the chapter analyses regionalisation by measuring the share of Mediterranean and Black Sea ports among the connections of each port, distinguishing between ports mainly embedded in regional circuits and ports maintaining broader extra-regional links. Finally, the chapter examines network vulnerability through targeted attack simulations and ego-network analysis, assessing how the removal of key hub ports affects the cohesion of the network and the centrality of Italian ports.

The results show a progressive strengthening of the hierarchical structure of Mediterranean container shipping networks. Hub functions are increasingly concentrated in a limited number of ports, especially Algeciras, Tangier Med and Valencia in the western Mediterranean, and Piraeus in the eastern Mediterranean. Italian ports occupy differentiated positions within this structure. Gioia Tauro maintains an important transhipment role, while several gateway ports show declining centrality, especially in terms of closeness and eigenvector centrality.

The spearman correlation between the hub dependency and the different variables analysed show that ports capable of generating larger traffic volumes, measured through TEU throughput and DWT, tend to display lower levels of dependency on external hubs. These ports are more likely to be directly integrated into international liner service networks and to maintain greater autonomy. Conversely, smaller ports tend to exhibit higher hub dependency, relying more strongly on feeder services, indirect connections and Mediterranean hubs. The analysis also shows that hub dependency is generally associated with lower closeness centrality, eigenvector centrality and node degree. This means that ports with higher dependency tend to occupy more peripheral positions within the global maritime network.

Finally, the highest Spearman's correlation coefficients were recorded in 2010 and 2020. This suggests that the 2008 financial crisis and the subsequent Covid-19 pandemic led to a higher hierarchy in traffic flow, making smaller and peripheral ports globally more dependent on hubs.

Chapter 3 extends the analysis from the port and regional scales to the global scale. The chapter investigates how maritime connectivity is unevenly distributed among countries within the global liner shipping network and how this unevenness shapes national vulnerability and maritime dependency. The analysis is based on the liner container services operated by the top 30 container shipping companies, which together account for the vast majority of global container fleet capacity.

This chapter therefore offers a global-scale analysis of the structure of the container maritime sector and seeks to address several key research questions: First, how are countries hierarchically positioned within the global liner shipping service network? Second, which countries display the highest levels of maritime peripherality and dependence on a limited number of carriers? Third, how do different service structures, namely, interoceanic, extra-regional and regional, shape national vulnerability? Finally, does a disruption scenario, such as the one currently affecting the Strait of Hormuz, confirm or challenge the vulnerability hierarchy identified through the analysis?

The answers to these questions provide an opportunity to understand the geographical structure of global maritime services, the varying degrees to which coastal countries are integrated into global container shipping networks, and which countries risk being disadvantaged by their peripheral location and limited autonomy in maritime transport.

The methodology combines network indicators and multivariate statistical analysis. First, for each country, the chapter measures the number of liner services, the number of companies operating those services, total deployed cargo capacity and the structure of maritime connections. Services are classified as regional, extra-regional or intercontinental. Second, it has been calculated the minimum number of transhipments required for each country to reach all other countries in the network. This measure is used to assess topological peripherality and to identify countries whose access to the global liner shipping system depends on longer indirect chains.

Third, it has been used the Principal Component Analysis to reduce the dimensionality of the dataset and identify the main latent dimensions of maritime connectivity, including service diversity, number of operators, distribution of cargo capacity and transhipment dependence. Fourth, k-means clustering is applied to classify countries according to their maritime connectivity profiles. The clustering procedure identifies different groups of countries, ranging from highly central and diversified maritime systems to peripheral and dependent countries with weak service structures.

The chapter also applies this vulnerability framework to a disruption scenario focused on the Strait of Hormuz. This analysis simulates two scenarios of exclusion of selected Gulf ports from the liner shipping network in order to evaluate the effect on connectivity of the global container maritime network and determine whether there is any correspondence between the k-means classification of the countries and the vulnerability to a real disruption such as the Hormuz crisis.

The results show that maritime connectivity is highly unequal at the global scale. Countries located along the main East-West corridors, especially in the Northern Hemisphere, tend to occupy more central and autonomous positions, benefiting from diversified services, multiple operators, intercontinental connections and lower dependence on transhipment. By contrast, many countries in the Southern Hemisphere, small island states and countries located outside the main corridors are more peripheral and dependent, often relying on fewer services, fewer carriers and longer transhipment chains. The Hormuz scenario further shows that the crisis appears to have its greatest impact on Gulf countries in terms of connectivity and It also suggests that the vulnerability patterns observed in the scenario partially confirm the clustering results..

Overall, the thesis demonstrates that vulnerability in maritime transport is intrinsically linked to dependence and centrality within liner services. The structure and organisation of these services by shipping companies, which pursue their own commercial strategies, influence the impact of crises on connectivity and maritime flows to ports within a country or region. The analysis across these three different scales provides insight into how the marked hierarchy and polarisation of maritime services influence inter-port competition and interdependence at local and inter-regional levels, and act as a limiting factor and source of vulnerability on a global scale.

The results of these analyses can provide insights not only into the academic understanding of the characteristics and dynamics of maritime transport, but also into issues of potential relevance to policymakers at different levels. At the port-management level, understanding how container flows and liner services have been redistributed following the outbreak of the Red Sea crisis can offer strategic insights into ports' relationships with shipping lines, particularly in the context of vertical integration, as well as into the relative importance of different liner services.

Moreover, the relationship between smaller ports and their dependence on hub ports, which tends to intensify during periods of crisis, as discussed in the second chapter, may help inform the development of resilience policies aimed at mitigating the risks of peripheralisation and disadvantage within trade networks. Similarly, the uneven distribution of maritime transport among coastal states, together with their dependence on a limited number of shipping companies, can help policymakers at both national and international levels assess how the structure of the global maritime network and market may give rise to high levels of market concentration, oligopolistic structures or, in extreme cases, monopolistic conditions, as well as dependency and vulnerability in certain countries.

Consequently, these findings can help identify the countries most at risk of being adversely affected by global disruptions, crises, or internal restructuring within the container shipping market.

# 2. Chapter 1: Winners and losers: the impact of the Red Sea crisis on Italian ports

## 2.1 Introduction

International trade is closely dependent on maritime transport. UNCTAD estimates that more than 80 per cent of all international trade in goods makes at least part of its journey by sea (UNCTAD, 2023). There is therefore a general interest in ensuring that such trade takes place safely and reliably as much as possible, given that the efficiency of many production processes and global value chains relies on those flows.

It is well known that one of primary global maritime routes connects Far East and Middle East to Europe and vice versa, passing through the Red Sea and the Suez Canal. Around one third of the world's containerised cargo and between 12 and 15 per cent of global freight traffic normally passes through Suez (UNCTAD, 2024). It is no coincidence that the Suez Canal is one of the so-called chokepoints of world maritime navigation.

Mediterranean ports, and hub ports in particular, have benefited from their geographical proximity to the shipping route through the Suez Canal and the Strait of Gibraltar. The canal gives the Mediterranean a strategic geographical position and has influenced the development of hub-and-spoke ports in the region (Prijon and Zohil, 1999; Fageda, 2000) as well as complementary logistics investments.

The Red Sea Crisis, hereafter abbreviated as RSC, began on 19th November, 2023 when the Houthi military forces in Yemen carried out the first attack on a ro-ro ship (The Galaxy Leader) navigating near the Strait of Bab el-Mandeb in consequence of the dramatic conflict occurring in the Gaza strip.

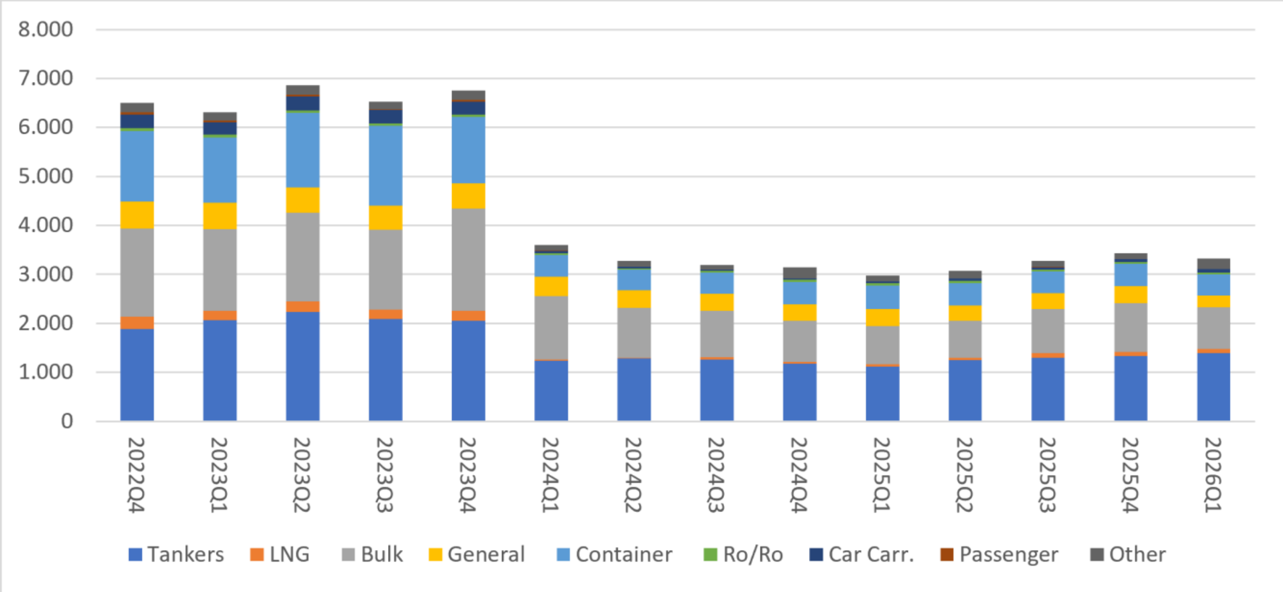
The Yemeni group began targeting ships directly or indirectly linked to Israel or heading for its ports. A series of attacks on commercial ships led to the suspension of services through the Red Sea by all major container shipping companies on 16th December 2023.

Most of the commercial ships that normally transited the Red Sea therefore began to by-pass the Red Sea and the Suez Canal by choosing the only alternative route available: the circumnavigation of Africa via the Cape of Good Hope. This route adds about 4,500 nautical miles to the distance between Shanghai and Rotterdam, which adds approximately 12 days to the voyage at an average speed of 16 knots (Haralambides, 2024). The same journey, assuming a direct journey without stopovers (a purely theoretical assumption in the field of liner shipping) and at the same average speed, adds approximately 14 days of sailing time for Genoa, 16 for Gioia Tauro and just around 17 for Trieste.

This is not the first time that this route has been disrupted by geopolitical conflicts. The Suez Canal was, in fact, closed three times between the 1950s and the 1970s. The first closure occurred in 1956 during the so-called Suez Crisis, following Nasser's nationalisation of the Canal and the subsequent Israeli invasion. The second occurred in 1967 during the Six-Day War, and the third in 1973 during the Yom Kippur War (Haralambides, 2024). These conflicts also led shipping companies to use the Cape of Good Hope route and prompted shipbuilders to build larger vessels to exploit scale economies.

As shown in Figure 1, the number of ships passing through the Suez Canal dropped by almost half between the last quarter of 2023 and the first quarter of 2024. Moreover, for certain types of ships, such as cruise ships and merchant ships carrying LNG and LPG, the number of transits seems to have fallen to zero at the beginning of 2024. As shown in Figure 1, the decline in transits along the Canal has essentially been maintained throughout the first quarter of 2024.

*Figure 1 Transits through the Suez Canal*

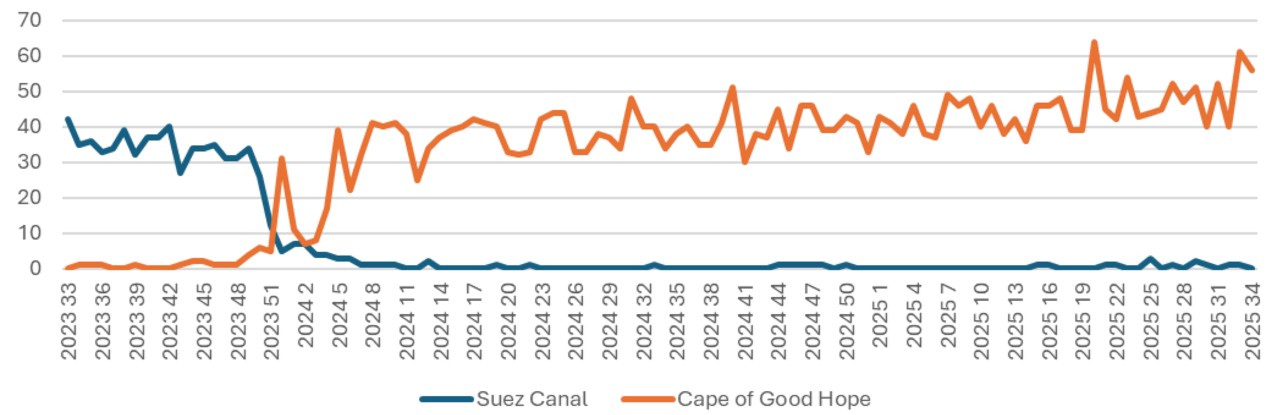



*Source: Suez Canal Authority*

The decision to avoid passing through the Canal also applies to larger container ships; according to data collected by Alphaliner, ships with a cargo capacity exceeding 15,200 TEU have almost all transited along the Cape of Good Hope route since the last weeks of 2023 (see Fig. 2).

Furthermore, to transport the same volume of goods at the same time and with the same frequency of port calls, the mass diversion of ships via the Cape of Good Hope requires significantly more capacity (Notteboom et al., 2024). This requires a reorganization of the maritime services that force operators to decide how to find the new optimum considering the size of their fleet, their networks and alliances agreements.

*Figure 2 Weekly transits through the Suez Canal of full-containerships 15,200+ TEU*




*Source: Alphaliner (2025)*

The possible options for shipping companies to adapt their supply to this new scenario imply a reorganization of commercial networks that could lead to different decisions:

- Reducing the number of services offered at ports, prioritizing certain routes over others;
- Changing the number of ports in their rotation, that could lead to skip some ports in order to reduce the time spent in ports by the ships and giving priority to some strategic ports (that could be the hub ports);

- Increasing the number of ports visited in some rotations in order to cover regions previously connected by different services or to concentrate enough freight flows to make the service economically viable;
- Changing the size of the vessels deployed in the rerouted services.

As observed in terms of connectivity by Ducruet (2016), the closure of the Suez Canal has the greatest impact on European ports in terms of the global maritime network. According to Notteboom et al. (2024) with respect to traffic on the Far East-Europe route, the Mediterranean Sea risks of becoming a maritime cul-de-sac, with maritime traffic entering and exiting the Mediterranean via the Straits of Gibraltar, thuds reducing the centrality of the Mediterranean ports.

Immediately after the outbreak of the RSC companies mainly favoured the transhipment ports in the western Mediterranean, close to the new route via the Cape of Good Hope, to the detriment of its eastern part (Yap and Yang, 2024).

Moreover, processes such as the vertical integration of liner companies, which may influence the decision of companies and alliances to maintain or include certain terminals in their liner services (Notteboom et al., 2017), may have influenced the carriers' response strategies.

This process of reorganising service schedules could result in certain ports becoming more marginalised due to the reduced connectivity (i.e. number of direct services). In this article, we use the terms 'marginalisation' and 'peripheralisation' to describe the phenomenon whereby a port loses liner services and experiences a decline in maritime traffic.

The present chapter aims at analysing the impact of this RSC on Italian ports, focusing on containerised liner transport. The analysis aims to answer the following research questions: have Italian ports been equally affected by the RSC, and which ports have proved to be the most competitive? Has the RSC led to the marginalisation of Italian ports? Has the RSC influenced the behaviour of carriers and alliances with regard to Italian ports?

The chapter is structured as follows: an introduction is followed by a brief review of the literature on the subject. Section 3 explains the methodology and data used. Section 4 is divided into five sub-paragraphs. The first of these analyses the performance of ports at a national level, followed by an analysis of each individual port. It compares the number of calls, cargo capacity, container traffic, and the time that ships spend in port for each quarter of 2023 and 2024. The second sub-paragraph analyses changes in maritime services and variations in the size of ships transiting ports. The third sub-paragraph presents the results of the Shift to Share analysis, hereinafter referred to as STS, identifying the most competitive ports and the possible factors influencing them. The fourth sub-paragraph analyses variation in ship size. The fifth sub-paragraph considers changes in the behaviour of carriers and alliances. Section 5 then presents the conclusions suggested by the analyses.

## 2.2 Insights from recent literature

As noted in the introduction, the structure of container shipping networks in the Mediterranean and the varying hierarchies among ports in the region have been strongly influenced by their proximity to the major Europe-Far East trade route passing through the Suez Canal (Prijon and Zohil, 1999; Fageda, 2000). The Mediterranean is a region with distinctive characteristics. On the one hand, it is a regional market, with internal trade and links to North Africa, Southern Europe and the Middle East; on the other, it is also a strategic transit zone along the Asia-Northern Europe and Asia-North America routes, thanks to the passage through the Suez Canal (Cazzaniga Franceschetti and Foschi, 2003).

Several studies have shown how this strategic location has led, since the 1990s, to a concentration of container flows on certain hub ports that are central to regional markets and situated close to the main shipping route (Notteboom 1997, Fageda, 2000, Notteboom 2010). This concentration has led to the development of a highly hierarchical and polarised structure within Mediterranean ports and the container shipping network (Foschi, 2002). Although this type of hierarchical organisation may be considered vulnerable because it relies on a small number of highly strategic ports, the Mediterranean maritime network has been deemed more resilient thanks to a dense network of regional services and is therefore potentially more resilient than other port regions that are heavily structured around a hub-and-spoke model, such as the Caribbean (McCalla et al., 2004).

The effects of external shocks on Italian ports have already been examined by Ferrari, Persico and Tei (2022) in relation to the Covid-19 pandemic. Their empirical analysis shows that the crisis affected Italian ports unevenly, reflecting differences in cargo composition, regional supply chains and exposure to international trade. The authors further find that larger and better-connected ports generally proved more resilient and recovered more rapidly than less connected port systems.

Crotti, Ferrari and Tei (2022) also investigate the consequences of the Covid-19 shock, focusing on the strategic responses of shipping lines and terminal operators. They argue that demand disruptions may encourage horizontal mergers and greater vertical integration, thereby increasing concentration within shipping and port markets. While integration can lead to efficiency gains, this is not always positive for consumers. Greater market power resulting from integration can reduce competition, throughput and consumer benefits.

Various analyses carried out prior to the RSC had shown that, globally, European ports would be the hardest hit in terms of connectivity by a blockage of the routes passing through the Suez Canal (Ducruet, 2016, Wu et al., 2019).

By analysing maritime vulnerability and dependence on global choke points using AIS data, Wang et al. (2024a) demonstrate that Mediterranean shipping is heavily dependent on the Suez Canal and the Strait of Gibraltar, though they assign greater weight to the latter than to the former.

Wan et al. (2023) examine the Suez Canal blockage as a targeted disruption to the global shipping network, showing that it reduced network connectivity, accessibility, and efficiency more severely than comparable random failures. With respect to Europe, the study finds that Mediterranean ports were particularly exposed due to their dependence on Suez-linked Asia-Europe routes. However, Europe as a whole appeared less vulnerable than other regions, as its diversified and developed transport system helped mitigate the disruption's network effects.

The impact of geopolitical conflicts on maritime transport in recent years has been analysed by examining various events. Fang et al. (2018) develop an AIS-based spatiotemporal framework to examine how international events may be reflected in changes to global maritime network dynamics. Their analysis shows that military conflict, economic sanctions, and political elections can be associated with substantial variations in shipping flows, including both direct and indirect effects across connected maritime links.

With the outbreak of open warfare in Ukraine in 2022, a number of authors have examined the impact of military conflicts on maritime transport, focusing primarily on changes in network connectivity and port operations, as well as shifts in the types of traffic, particularly with regard to energy commodities (Cong et al., 2024; Chen et al., 2025; Polo-Martín et al., 2025; Liu et al., 2025).

The short-term effects of the RSC on the maritime sector been have recently investigated by several scholars adopting different perspectives.

Using AIS data, Wang et al. (2024b) observe changes in the behaviour of vessels and the global maritime network. In the short term, network analysis measures revealed an increase in alternative routes and nodes, demonstrating the resilience of maritime transport to these shocks. However, the average path length has increased and the hierarchical positions of hub ports have changed.

In their work, Peng et al. (2024) observe, through the analysis of AIS data and the calculation of the distance of the new route passing through the Cape of Good Hope, how the increase in distance and navigational speed of ships, as well as the possible use of hub ports on the east coast of Africa, leads to an increase in greenhouse gas emissions and possible malfunctions in the calculation of the EU carbon pricing framework.

Bedoya-Maya et al. (2025) also use AIS data to observe the effects of the crisis on European maritime networks in the first half of 2024. They use network analysis and a transport-chain cost model to estimate changes in transport costs along the new routes. Their results show that in terms of connectivity, Eastern Mediterranean hub ports experienced the largest reductions in connectivity and the greatest increases in transport costs, resulting in greater peripheralisation. Genoa was the port with the highest increase in transport costs. The hub ports near the Strait of Gibraltar, on the other hand, showed a sharp increase in connectivity.

Similar results are obtained by Yap et al. (2024), who observed, again using AIS data, that the greatest reduction in port calls and cargo capacity by maritime alliances on the Asia-Far East route occurred at the hub ports of the Eastern Mediterranean and the Red Sea, to the benefit of the hub ports of the Western Mediterranean.

Yang et al. (2025) used AIS data and service information to analyse the port skipping rate of maritime alliances, observing how companies skipped port calls in order to maintain frequency and how some hub ports, such as Colombo and Tanger Med, were less affected than others by the phenomenon.

Hamdan et al. (2025) show how the variation in the distance of the new route passing through the Cape of Good Hope changes the optimum for managing the number of calls and the size of services for the Europe-Far East line, and how the addition of calls at African ports can make the route profitable even with smaller ships.

Liu et al. (2025) examine the impact of the Red Sea crisis on the global LNG shipping network using AIS data and directed weighted network analysis. They find that, although rerouting via the Cape of Good Hope increased sailing distances and reduced distance-based efficiency, the crisis did not substantially weaken overall network performance. Instead, the LNG network became more fragmented and less vulnerable, suggesting an adaptive reconfiguration of LNG flows under geopolitical disruption. Liu et al. (2026) developed a data-driven framework for assessing port resilience during the Red Sea crisis. This framework used daily congestion indices and machine learning models to identify congestion anomalies. Their study revealed significant heterogeneity among ports and regions, with Algeciras, Antwerp, and Busan demonstrating greater resilience, while Barcelona, Colombo, and Port Klang appeared more vulnerable.

Li et al. (2026) use a multilayer weighted port-to-port network, combining liner shipping schedules, UNCTAD connectivity indices and bilateral trade-value data, with CONCOR-based cluster analysis to examine functional reorganisation during the Red Sea crisis. They show that the crisis redistributed port-cluster functions, reducing the centrality of several Eastern Mediterranean and Red Sea ports, including Alexandria, Port Said and Jeddah. At the same time, resilience increasingly depended on alternative tropical and Southern Hemisphere corridors, flexible bridge ports, parallel gateways and stronger sea-land intermodal coordination.

Bordeaux and Couto (2026) analyse the increase in volatility of transhipment traffic at hub ports following the RSC. In the Mediterranean, the crisis has weakened the position of transhipment ports in the eastern Mediterranean and the Red Sea, such as Piraeus, Jeddah and King Abdullah, whilst increasing the importance of western Mediterranean hubs near Gibraltar, including Tanger Med, Algeciras and Valencia. The study therefore highlights the fluid nature of transhipment traffic, as the reconfiguration of carrier services has rapidly shifted volumes and connectivity between Mediterranean hubs.

## 2.3 Data and methodology

The analysis presented in this paper focuses on the ten leading Italian ports in terms of volume of containers moved. The evolution of maritime containership traffic is considered. Particular attention is paid to to changes in the structure of liner services, variations in throughput, and shifts in the market shares of individual ports.

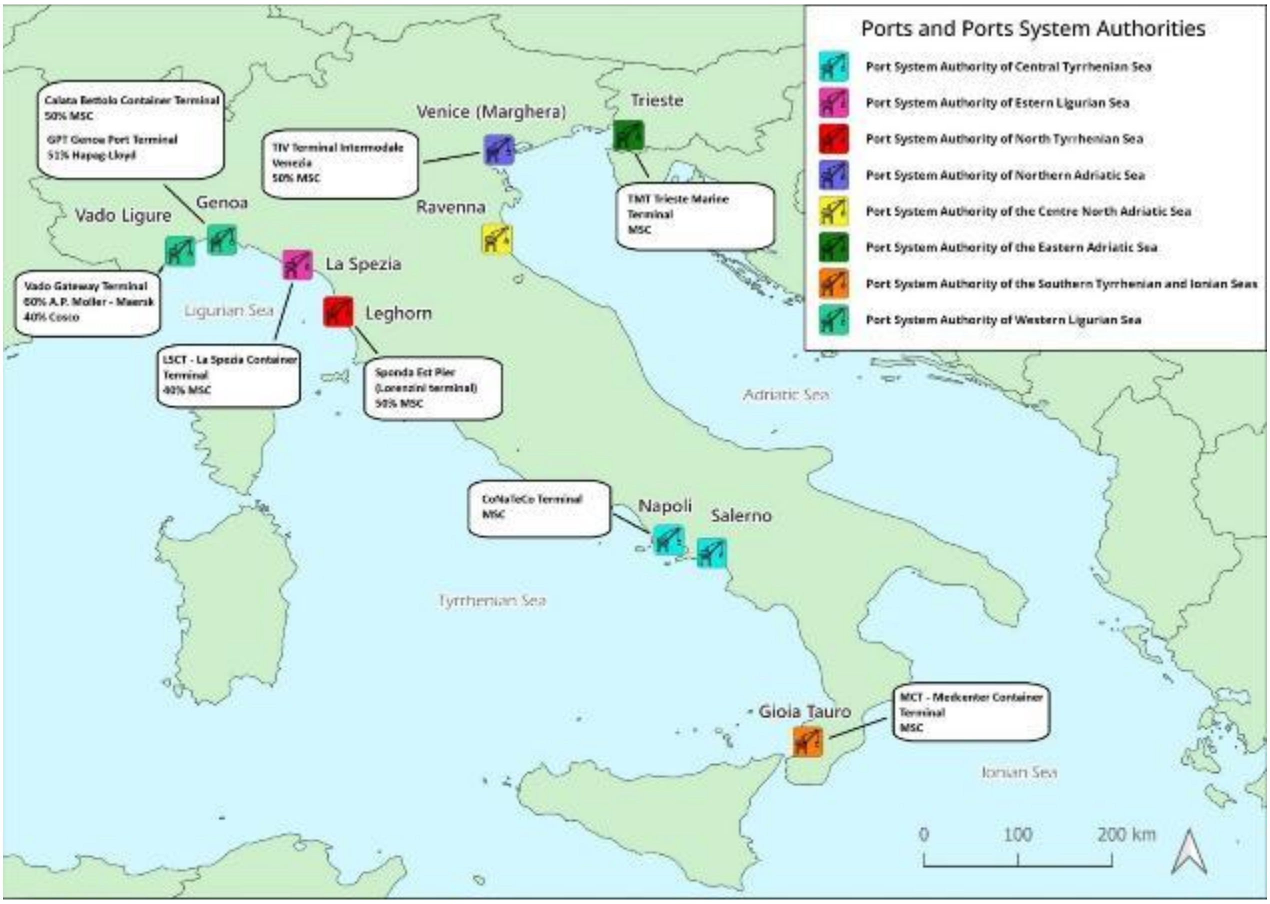
In 2023 the selected ports represented 94 per cent of Italy’s total container traffic (ASSOPORTI,2023).

As can be seen in Figure 3 the ports under analysis are geographically distributed along both the Tyrrhenian and Adriatic coasts. The ports of the Tyrrhenian coast are Vado Ligure, Genoa, La Spezia, Leghorn, Naples and Gioia Tauro while Ravenna, Venice and Trieste are located on the Adriatic coast.

Data on port calls from the last quarter of 2022 to the last quarter of 2024 were collected in order to conduct the research. The dataset records the names of the ships, the capacity of the ships (expressed in TEU), the vessel operator, the name of the service to which the ship belongs and the dwelling time in port. The dataset was constructed by integrating information from a range of sources, including Alphaliner, the official websites of Port Authorities and liner shipping companies, Econdb, and Assoporti.

The first research question was addressed using two methodologies. To address the first part of the question, as outlined in the introduction, a comparative analysis was carried out to examine changes in the number of port calls, total cargo capacity, defined as the sum of the TEU capacity of all vessels calling at the ports, and average vessel dwell time. The analysis was conducted both at the national and port levels. In addition, actual container throughput in 2023 and 2024 was examined, and changes in the average number of containers handled per vessel were calculated, measured as TEU handled divided by the number of calls.

*Figure 3 Italian ports in analysis and vertically integrated container terminals*




To address the first research question “Have Italian ports been equally affected by the RSC, and which ports have proved to be the most competitive?”, the analysis examined, on the one hand, changes in the structure of container shipping supply.

These were assessed through the number of port calls; the total cargo capacity, calculated as the sum of the cargo capacity of all vessels calling at the port during the selected period; and the number and type of liner shipping services offered by carriers at each port.

On the other hand, changes in trade-flow-related performance were evaluated by considering variations in port throughput measured in TEUs; the average cargo volume handled per vessel call, calculated by dividing annual TEU throughput by the number of port calls recorded in the same year, and the annual average berthing time of the ships.

Furthermore, in order to assess the dynamics of inter-port competition and identify the factors that may have influenced competitive dynamics, a two-component Shift-to-share (STS) analysis was conducted in Section 4.3. The results are analysed in relation to changes in the scheduled services of the three groups under observation operating in each port. This methodology, developed in the field of regional economics (Dunn, 1960), was adapted to container-throughput data to assess changes in a port’s competitive position relative to a group of other ports in proximity (Marti, 1988, Notteboom, 1997, Fageda, 2000).

Although Shift-To-Share analysis cannot capture immediate changes in the competitive environment, it enables a variable's growth or decline to be decomposed into two key components: the share effect and the shift effect. The two-component STS analysis is based on changes in container throughput between 2023 and 2024.

The share effect represents the expected increase in a port's container throughput if it were to maintain its market share, thereby mirroring the growth rate of the entire sample of ports.

The total shift quantifies the number of containers (in TEUs) that a port has gained or lost due to competition within the group, using the expected throughput (i.e. the share effect) as a benchmark. The shift effect provides a clearer assessment of a port's competitive position by isolating net volume transfers between ports and effectively eliminating overall growth in the container sector. The sum of the shift effects across all ports is always equals to zero.

*Eq. 1*

$$ABSGR_i = TEU_{it1} - TEU_{it0} = SHARE_i + SHFT_i$$

*Eq. 2*

$$SHARE_i = \left(\frac{\sum_{i=1}^{n} TEU_{it1}}{\sum_{i=1}^{n} TEU_{it0}} - 1\right) TEU_{it0}$$

*Eq. 3*

$$SHIFT_i = TEU_{it1} - \frac{\sum_{i=1}^{n} TEU_{it1}}{\sum_{i=1}^{n} TEU_{it0}} \, TEU_{it0}$$

*ABSGRi* is the absolute growth of container traffic in port *i* for the period $t_1$-$t_0$, expressed in *TEU*, *SHAREi* is the share-effect of port *i* for the period $t_1$-$t_0$, expressed in *TEU*; it represents the number of containers that port i would theoretically have handled if it had retained its 2023 market share. *SHIFTi* is the total shift of port i for the period $t_1$-$t_0$, expressed in *TEU.* The SHIFT effect reflects how much the number of containers handled in a port in $t_1$ has changed compared to the SHARE. *TEUi* is the container traffic of port *i* expressed in *TEU*, and n is the number of ports.

*Table 1 Classification of the routes served by liner services calling at ports in Italy.*

| **Suez** |
|---|
| *Asia / North America* |
| *Europe - Middle East and South Asia* |
| *Europe - South and East Africa* |
| *Med - Far East* |
| *North America -Med - Middle East - Far East* |
| *North Europe - Med - Middle East and South Asia - Oceania* |
| *North Europe - Med - North America - Middle East and South Asia* |
| **Gibraltar** |
| *Europe - South America West Coast* |
| *Europe - West Africa* |
| *Med - Central America and Caribbean* |
| *Med - Central America and Caribbean -South America* |
| *Med - North America* |
| *Med - South America* |
| *North Europe - Med* |
| *North Europe - Med - North America* |
| *North Europe - Med - North America - Middle East and South Asia* |
| *North Europe - Med - North America-Central America -South America* |
| **Intra Mediterranean** |
| *Intra Mediterranean* |

The second research question on ports peripheralisation was tackled by analysing the changes in scheduled services by group-of-routes, first at national level and then at port level. The liner services have been classified into three groups, as can be seen in Table 1, depending on their geographical route before the crisis: the services that sailed through the Suez Canal before the crisis, the services that sailed through the Strait of Gibraltar before the crisis and the Intra-Mediterranean routes.

To perform this analysis, we calculated the changes in the average number of services, number of calls per service, and the number of operators. The number of services at each port was compared for the pre-crisis year and the post-crisis year. The difference between these two numbers was calculated for each port. This measure provides information on whether the analysed ports have become peripheral and insight into how shipping companies have restructured their services following the Red Sea blockade.

The last research question on carriers and alliances behaviour was examined comparatively, by analysing changes in the size of ships calling at the ports before and after the RSC, and classifying them into four categories by size (0-4,999 TEU, 5,000-9,999 TEU, 10,000-18,000 TEU, more than 18,000 TEU). Carriers were analysed by comparing their cargo capacity and relative market distribution across the main Italian container ports. The five largest carriers by global fleet capacity (MSC, Maersk, CMA CGM, COSCO, Hapag-Lloyd) were examined individually, while the remaining top-ten operators (ONE (Ocean Network Express), Evergreen line, HMM, Yang Ming Marine Transport Corp., ZIM) and smaller carriers were grouped into broader categories. Their quarterly performance was assessed by observing changes in capacity distribution, port presence and concentration levels. Alliances were analysed through the cargo capacity and number of calls generated by their scheduled services. Comparisons by quarter, port and trade route were then used to identify changes in service frequency, capacity deployment and network configuration.

## 2.4 The Red Sea Crisis impact in Italian ports

### 2.4.1. Variation in performances

Following the onset of the RSC, some companies decided to avoid transiting the Suez Canal. In the following weeks, the number of ships taking the same decision increased sharply, although rerouting entailed longer voyages, higher bunker consumption and delayed arrivals. This decision will lead to an increase in operating costs due to longer routes and the higher speeds required to minimise delays and ensure the reliability of scheduled services.

*Table 2 Containers traffic in ports*

| Port | TEU 2023 | TEU 2024 | Annual Increase | Annual Increase (%) |
|---|---|---|---|---|
| **Vado Ligure** | 346612 | 372686 | 26074 | 7,5% |
| **Genoa** | 2394335 | 2447817 | 53482 | 2,2% |
| **La Spezia** | 1139088 | 1238258 | 99170 | 8,7% |
| **Leghorn** | 669414 | 663622 | -5792 | -0,9% |
| **Naples** | 595740 | 646409 | 50669 | 8,5% |
| **Salerno** | 345949 | 358316 | 12367 | 3,6% |
| **Gioia Tauro** | 3548830 | 3940452 | 391622 | 11,0% |
| **Ravenna** | 216981 | 201776 | -15205 | -7,0% |
| **Venice** | 491118 | 478837 | -12281 | -2,5% |
| **Trieste** | 852193 | 842200 | -9993 | -1,2% |
| **Total traffic** | 10,600,260 | 11,190,373 | 590,113 | 5,6% |

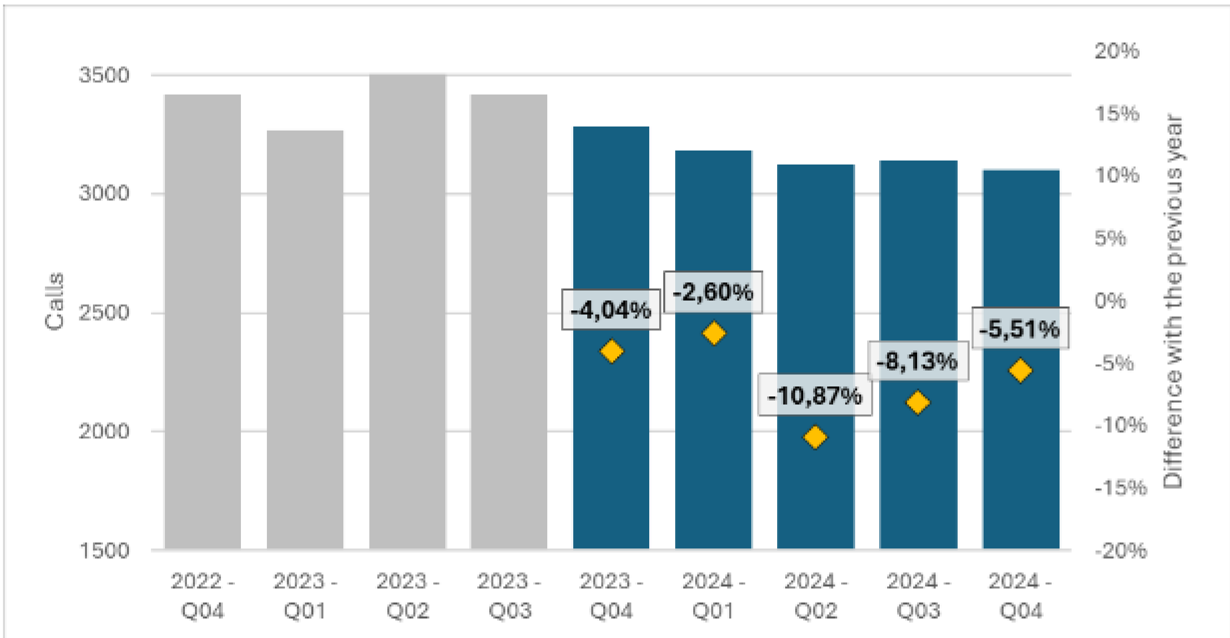
*Source: Assoporti 2023,2024*

Table 2 shows that, despite this new situation at national level, container traffic increased by more than 590,000 TEUs between 2023 and 2024, though not uniformly across all Italian ports.

In fact, Table 2 highlights an increase in container throughput for all Tyrrhenian ports except Leghorn. By contrast, Adriatic ports were the most affected despite their gains in cargo capacity. Gioia Tauro has driven this growth, with an increase of more than 390,000 TEUs in the volume of containers handled, indicating that its role as a transhipment hub in the Mediterranean has been strengthened during the crisis.

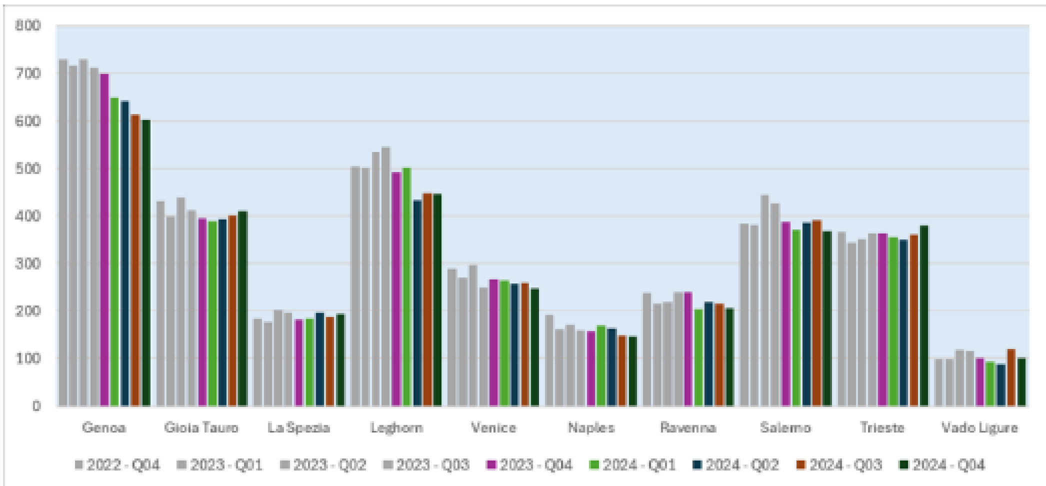
By contrast, the pattern of port calls at the national level reveals a trend in the opposite direction. Figure 4 illustrates the nationwide reduction in calls since the beginning of the RSC. All the quarters after the start of the crisis, highlighted in blue, recorded a reduction compared to the quarters of the previous year. The largest reduction was recorded in Q2 and Q3 of 2024. This may suggest that these quarters represented the period of greatest impact due to the reorganisation of shipping routes following the onset of the crisis.

*Figure 4 Number of ports calls in Italian ports*




*Source: Own elaboration based on Alphaliner and port system authorities' data*

*Figure 5 Number of containerized trade port calls by port and by quarter*




*Source: Own elaboration based on Alphaliner and port system authorities' data*

Notwithstanding, as for TEU traffic, any single ports performed differently as highlighted in Figure 5 that reports the number of calls by quarter. Overall, the crisis has led to a reduction in calls at almost all ports.

*Table 3 Changes in the number of calls by quarter*

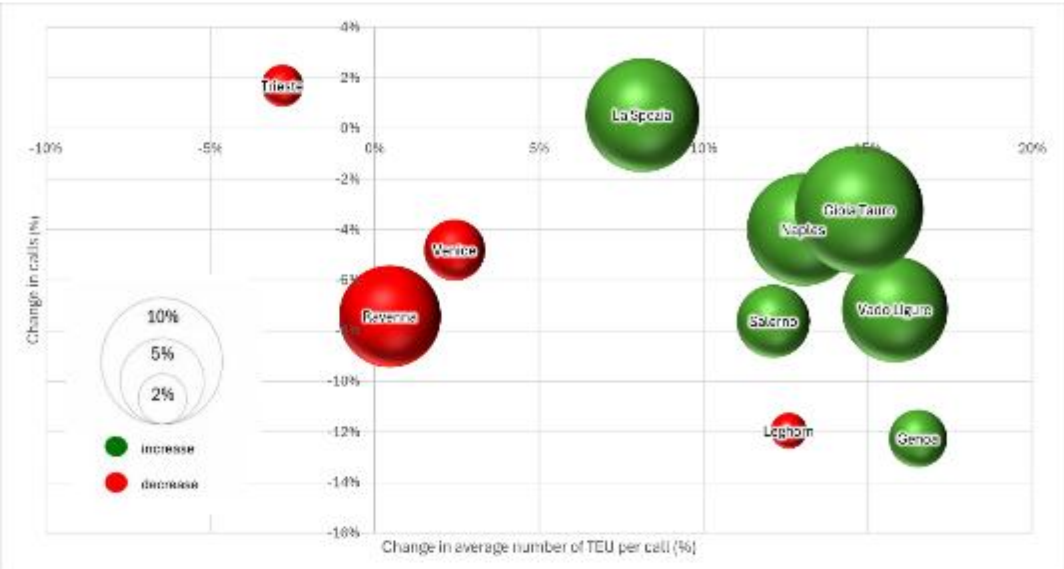
| Ports | Q4 2023-2022 | Q1 2024-2023 | Q2 2024-2023 | Q3 2024-2023 | Q4 2024-2023 |
|---|---|---|---|---|---|
| **Vado Ligure** | 1 | -6 | -30 | 4 | 1 |
| **Genoa** | -32 | -67 | -89 | -98 | -96 |
| **La Spezia** | -2 | 7 | -6 | -9 | 12 |
| **Leghorn** | -12 | -1 | -102 | -98 | -47 |
| **Naples** | -35 | 6 | -8 | -13 | -11 |
| **Salerno** | 4 | -12 | -58 | -36 | -19 |
| **Gioia Tauro** | -36 | -9 | -47 | -12 | 15 |
| **Ravenna** | 2 | -10 | 0 | -24 | -34 |
| **Venice** | -24 | -5 | -39 | 10 | -18 |
| **Trieste** | -4 | 12 | -2 | -2 | 16 |

*Source: Own elaboration based on Alphaliner and port system authorities' data*

Figure 5 shows that Genoa and Leghorn remain the ports with the highest number of port calls even if, as shown in **Errore. L'origine riferimento non è stata trovata.**, the two ports show the highest reductions compared with the corresponding quarters of the previous year. The least impacted ports are Trieste, La Spezia and Vado Ligure.

Despite the huge increase in throughput Gioia Tauro registered a reduction of calls in every quarter until Q4 2024, when it shows a partial recovery. This apparent contradiction between an increase in commercial traffic and a decrease in port calls suggests that, during the crisis, there was a greater concentration of cargo per ship.

*Figure 6 Relationship between changes in average TEU per call and changes in the number of calls. The bubble size represents the absolute percentage change in container throughput (TEU) while green and red indicate increases and decreases, respectively. Source:*




The graph in Figure 6 shows the year-on-year change between 2023 and 2024; the x-axis represents the change in average number of TEU per call as a percentage, whilst the y-axis represents the percentage change in the number of calls. As can be seen overall, the Tyrrhenian ports experienced a greater increase in cargo volume per call than the Adriatic ports, with increases of over 8 per cent across the board and even higher increases for the ports of Gioia Tauro, Vado Ligure and Genoa. For all these ports except Leghorn, this has also been accompanied by an increase in throughput in TEU. La Spezia is the only port that shows a positive trend in terms of both calls and average number of TEU per call, indicating an increase in the number of ships and their average cargo load. In contrast, Trieste experienced a higher number of calls in 2024, but with a lower average cargo load compared to 2023.

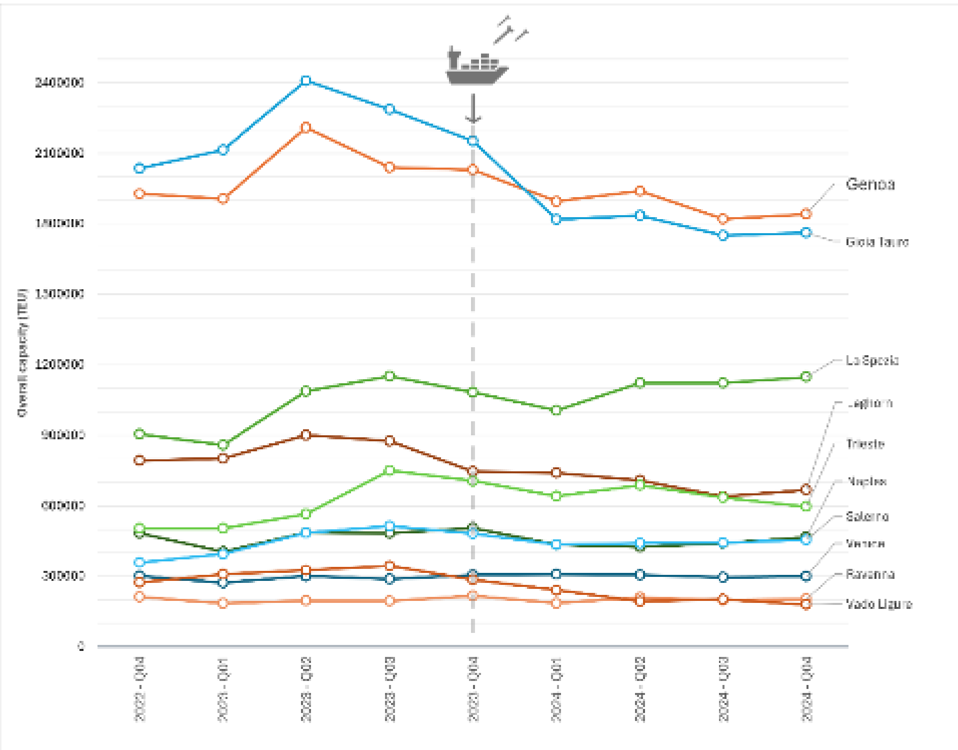
This phenomenon also seems to be confirmed by the change in the average time that ships spent in port between 2023 and 2024. As can be seen in Table 4, there was an increase in eight out of ten ports. As can be seen, the largest increase was at the port of La Spezia, where there was a rise in both the number of calls and the cargo per ship.

*Table 4 Average time spent in ports by ships*

| Ports | Average h 2023 | Average h 2024 | Variation |
|---|---|---|---|
| **Vado Ligure** | 18,0 | 19,1 | 1,1 |
| **Genoa** | 25,5 | 28,4 | 2,9 |
| **La Spezia** | 27,7 | 33,7 | 6,0 |
| **Leghorn** | 19,5 | 21,0 | 1,5 |
| **Naples** | 33,7 | 33,9 | 0,2 |
| **Salerno** | 14,4 | 15,1 | 0,7 |
| **Gioia Tauro** | 32,8 | 35,0 | 2,2 |
| **Ravenna** | 30,6 | 28,0 | -2,6 |
| **Venice** | 28,4 | 30,3 | 1,8 |
| **Trieste** | 22,2 | 21,3 | -0,9 |

*Source: Own elaboration based on Alphaliner and port system authorities' data*

*Figure 7 Overall cargo capacity by ports*



*Source: Own elaboration based on Alphaliner and port system authorities' data*

As shown in Figure 7, the total capacity of ships, calculated as the sum of the capacities of all ships calling at each port, has changed since the start of the RSC. In the first quarter of 2024 a decrease was recorded in almost all ports. Gioia Tauro recorded the largest reduction and was overtaken by Genoa in terms of the overall capacity transited in port. In fact, despite a reduction trend for both ports, Genoa gains the first position for cargo capacity.

Table 5 shows that the Adriatic ports (Ravenna, Venice and Trieste) were affected later by this decline, although Trieste recorded the most drastic decline in the last two quarters. La Spezia however, bucked the trend, recording an increase in cargo capacity compared with 2023, (only in 2024 Q3, the values are a bit lower than that of 2023). Leghorn, by contrast, recorded a continuous decline in all five quarters.

*Table 5 Variation in overall capacity (TEU)*

| Ports | Q4<br>2023-2022 | Q1<br>2024-2023 | Q2<br>2024-2023 | Q3<br>2024-2023 | Q4<br>2024-2023 |
|---|---|---|---|---|---|
| **Vado Ligure** | 11757 | -67474 | -133357 | -142704 | -105731 |
| **Genoa** | 102857 | -11527 | -271109 | -222229 | -189855 |
| **La Spezia** | 177080 | 147606 | 34730 | -29241 | 64590 |
| **Leghorn** | -46375 | -61662 | -191957 | -237129 | -78095 |
| **Naples** | 22439 | 30327 | -60913 | -41911 | -39722 |
| **Salerno** | 123281 | 40676 | -43409 | -71249 | -26310 |
| **Gioia Tauro** | 116794 | -297758 | -575213 | -537755 | -391801 |
| **Venice** | 3213 | 36062 | 5187 | 7295 | -5283 |
| **Ravenna** | 4389 | 805 | 12234 | 2840 | -13368 |
| **Trieste** | 201372 | 137872 | 122778 | -115132 | -109778 |

*Source: Own elaboration based on Alphaliner and port system authorities' data*

## 2.4.2. Variation in services

In order to observe how the connectivity of Italian ports has changed since the beginning of the RSC, this study considered the maritime services calling at the same port at least twice a month during the period under analysis.

As previously mentioned, services have been organised into three groups of routes to distinguish the direct effect of the closure of the Red Sea passage and the longer route via the Cape of Good Hope.

Furthermore, the number of maritime services calling at a port is also subject to seasonal fluctuations; therefore, our analysis is based on the annual average number of active services in 2023 and 2024.

Table 6 shows that Genoa was the port with the highest number of services in all the three groups-of-routes in 2023, but in 2024 all groups experienced a reduction. Although it remains the port with the highest number of services transiting through Suez, Genoa suffered the greatest reduction, losing two direct services. Along with Genoa, Salerno is the only other Italian port that recorded a reduction in the number of services in all the three groups of routes.

Compared to the Suez groups of routes, the only ports that maintained in 2024 the same number of services as in the previous year or recorded a slight increase were Naples and Trieste, although even for La Spezia the reduction was minimal. Naples recorded the largest increase in direct service connectivity. In Gioia Tauro the reduction in services transiting the Suez Canal has been replaced by a sharp increase in the 'Gibraltar' group, mainly connecting Gioia Tauro to the American continent, as well as in the intra-Mediterranean services.

Finally, we observe that this crisis has led to a more pronounced regionalisation of liner services for the ports of Vado Ligure, Naples, Gioia Tauro and La Spezia, while all the Adriatic ports experienced a decline.

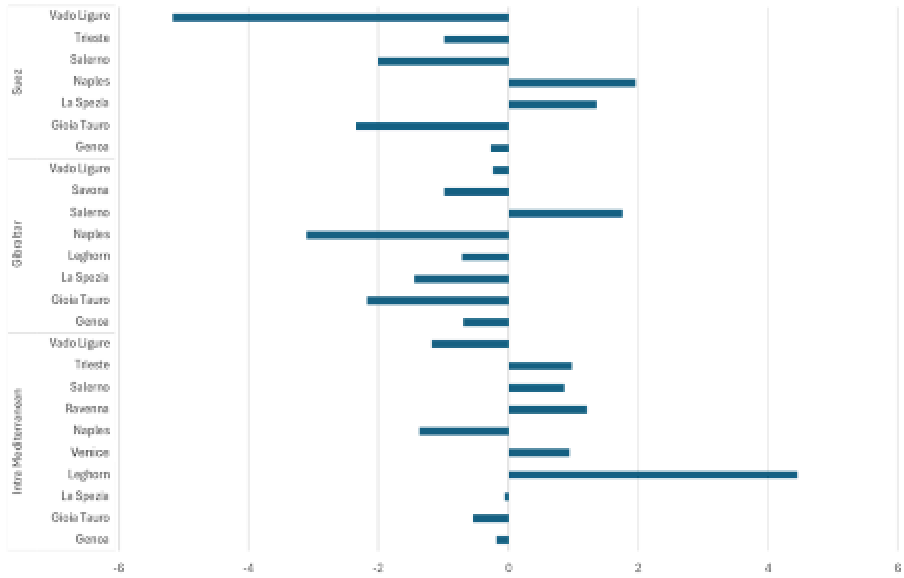
As mentioned in the introduction, a longer route also means more days spent at sea and, in order to maintain the scheduled frequency of calls, more ships must be deployed on each service.

*Table 6 Variation of number of services (annual means) in port in the Groups-of-routes*

| Port | Group of Routes | 2023 | 2024 | Variation |
|---|---|---|---|---|
| **Vado Ligure** | Intra Mediterranean | 5,0 | 7,8 | 2,8 |
| | Gibraltar | 3,0 | 2,0 | -1,0 |
| | Suez | 1,8 | 1,0 | -0,8 |
| **Genoa** | Intra Mediterranean | 18,3 | 17,5 | -0,8 |
| | Gibraltar | 13,8 | 12,5 | -1,3 |
| | Suez | 10,8 | 8,8 | -2,0 |
| **La Spezia** | Intra Mediterranean | 7,0 | 7,5 | 0,5 |
| | Gibraltar | 6,5 | 5,8 | -0,8 |
| | Suez | 4,8 | 4,5 | 0,0 |
| **Leghorn** | Intra Mediterranean | 8,0 | 6,8 | -1,3 |
| | Gibraltar | 11,3 | 11,8 | 0,5 |
| | Suez | 1,3 | 0,0 | -1,3 |
| **Naples** | Intra Mediterranean | 7,5 | 9,5 | 2,0 |
| | Gibraltar | 4,0 | 4,8 | 1,0 |
| | Suez | 1,7 | 1,8 | 0,0 |
| **Salerno** | Intra Mediterranean | 15,0 | 13,5 | -1,5 |
| | Gibraltar | 10,0 | 9,3 | -0,8 |
| | Suez | 2,3 | 1,0 | -1,3 |
| **Gioia Tauro** | Intra Mediterranean | 13,8 | 15,3 | 1,5 |
| | Gibraltar | 9,5 | 13,3 | 3,8 |
| | Suez | 7,5 | 6,3 | -1,3 |
| **Ravenna** | Intra Mediterranean | 13,5 | 12,3 | -1,3 |
| **Marghera (Ve)** | Intra Mediterranean | 17,5 | 16,8 | -0,8 |
| **Trieste** | Intra Mediterranean | 13,5 | 13,0 | -0,5 |
| | Suez | 2,0 | 2,0 | 0,0 |

*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data.*

*Figure 8 Difference in average number of calls per services between 2023 and 2024*




*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data*

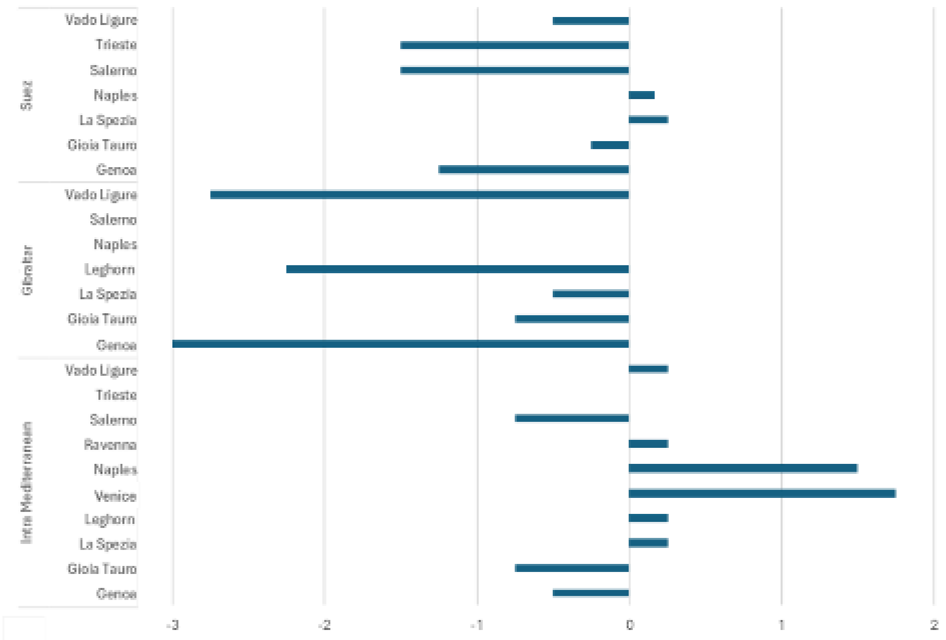
Figure 8 shows that, after the onset of the RSC, there was a reduction in call frequency (average calls per service) between 2024 and 2023 for both Suez and Gibraltar groups. However, service frequency increased in five of the ten ports analysed for intra-Mediterranean services.

Naples and La Spezia not only did not experience a significant loss in the number of Gibraltar group services, but they are also the only ports to have increased the frequency of liner services.

Finally, in Figure 9 it can be observed that the change in the structure of scheduled services after the RSC has also influenced the number of maritime operators providing services in ports.

There has also been a decline in the number of operators on extra-Mediterranean routes. The only significant increase in the number of operators has been recorded on intra-Mediterranean routes in Naples and Marghera. This probably means that ports became more dependent on a smaller number of liner operators for extra-regional connections.

*Figure 9 Difference between 2024-2023 in number of operators*




*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data*

### 2.4.3. Port competitiveness

In order to understand which ports have demonstrated the highest level of competitiveness and identify the possible reasons, a Shift-to-Share analysis was carried out.

This method allows us to observe changes in the competitive position of a port relative to a group of other ports based on a hypothetical market share in t1 calculated from t0 and the relative shift from this hypothetical value.

Table 7 reports the results of the analysis. The SHIFT effect reflects how much the number of containers handled in a port has changed compared to the SHARE value, which represents the number of containers that the port would theoretically have handled, given its market share of 2023.

The results show that, although throughput increased at most ports on the Tyrrhenian coast, two ports experienced a negative shift effect. Despite the increase in traffic, Genoa and Salerno appear to have lost potential traffic.

In absolute terms, Gioia Tauro and La Spezia are the ports that have gained market share, followed by Naples and Vado Ligure. Genoa and Trieste relatively lost the largest number of containers, followed by Livorno, Venice, Ravenna and Salerno.

*Table 7 Container traffic and Shift to Share results*

| Port | TEU 2023 | TEU 2024 | ABSGR | SHARE | SHIFT |
|---|---|---|---|---|---|
| **Vado Ligure** | 346612 | 372686 | 26074 | 19296 | 6778 |
| **Genoa** | 2394335 | 2447817 | 53482 | 133292 | -79810 |
| **La Spezia** | 1139088 | 1238258 | 99170 | 63413 | 35757 |
| **Leghorn** | 669414 | 663622 | -5792 | 37266 | -43058 |
| **Naples** | 595740 | 646409 | 50669 | 33165 | 17504 |
| **Salerno** | 345949 | 358316 | 12367 | 19259 | -6892 |
| **Gioia Tauro** | 3548830 | 3940452 | 391622 | 197562 | 194060 |

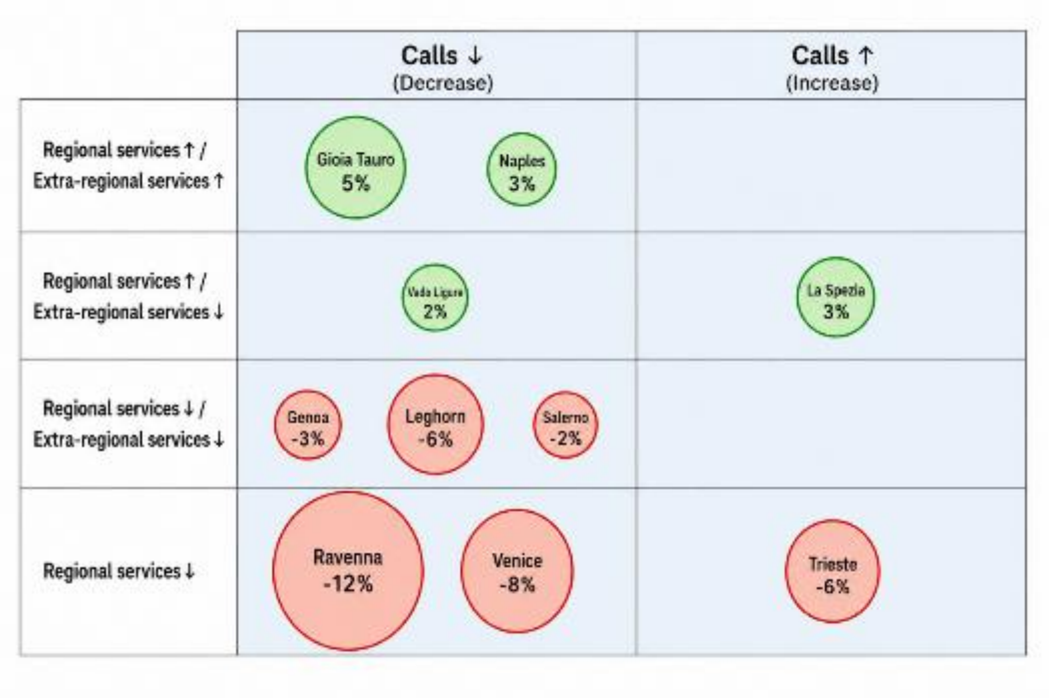
| | | | | | |
|---|---|---|---|---|---|
| **Ravenna** | 216981 | 201776 | -15205 | 12079 | -27284 |
| **Venice** | 491118 | 478837 | -12281 | 27340 | -39621 |
| **Trieste** | 852193 | 842200 | -9993 | 47441 | -57434 |

Using the graph in Figure 10, we attempted to observe whether the changes in the number of calls and the increase in the number of regional or extra-regional services had influenced improvements in each port's relative share of container traffic.

Ports were positioned within the various boxes based on the decrease/increase in calls and the decrease/increase in the number of regional or extra-regional services based on the values shown in Table 6.

Green labels characterise positive SHIFT values, whereas red labels indicate negative values. The size of the circles represents the hypothetical impact of the SHIFT on a port's traffic volumes. The percentage shown inside the circles was calculated by adding the SHARE to the 2023 traffic figures and then calculating the percentage difference compared with the traffic actually recorded in 2024. It is therefore a percentage relating to each individual port's share of traffic.

*Figure 10 Classification of the ports according to changes in regional and extra-regional services and calls. Circle size represents the percentage impact of the SHIFT on the hypothetical traffic growth.*



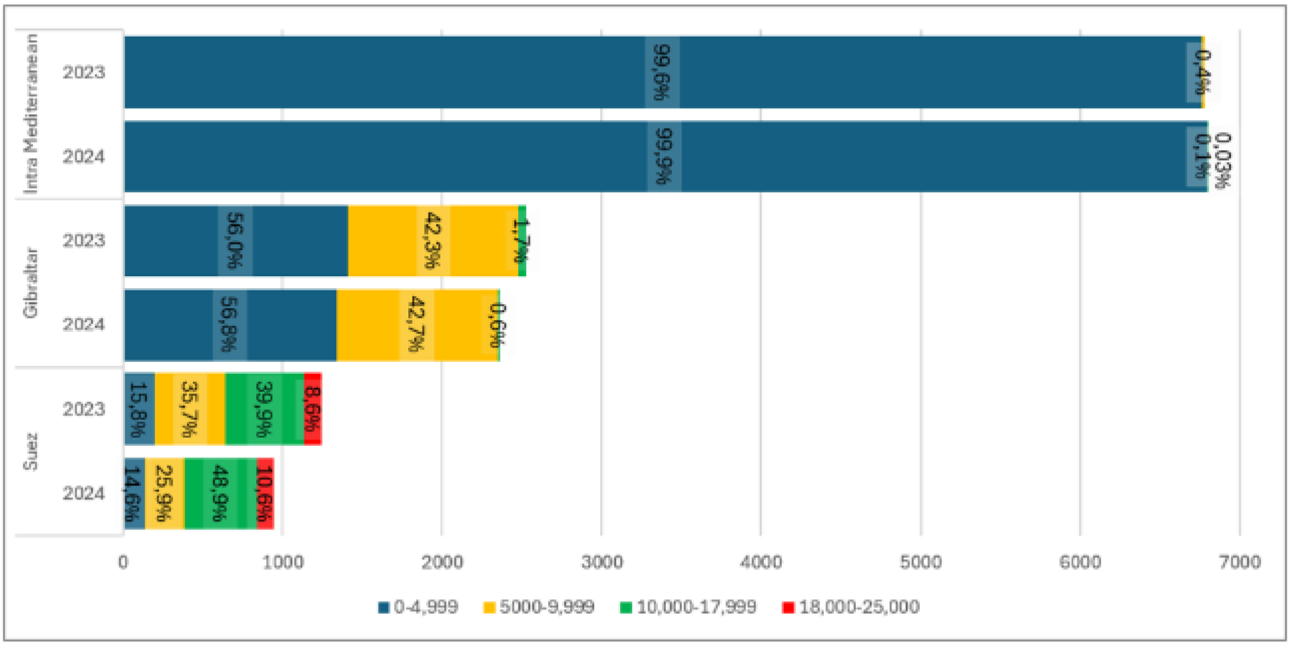

The figure shows some visible patterns. The first is that an increase in regional services is a common feature of all ports that have increased their market share. The increase in both types of services has benefited two of the top three ports with the highest relative growth.

The second is that all ports that all ports with a negative shift effect have also lost regional services. Geographically speaking, it is confirmed that the Adriatic ports have been severely affected and have seen a decline in competitiveness compared with ports on the other coast, with the exception of the port of Livorno.

## 2.4.4. Changes in vessels' size

As previously anticipated, the Italian ports have been affected by the reorganisation of the maritime liner services. This new geographical configuration of Mediterranean shipping caused by the RSC had an impact on the ships deployed by the liner companies on the loops calling at the Mediterranean ports. This section, therefore, will consider changes in the size of vessels calling at the Italian ports.

*Figure 11 Number of calls per size class and percentage of the class on groups of routes.*



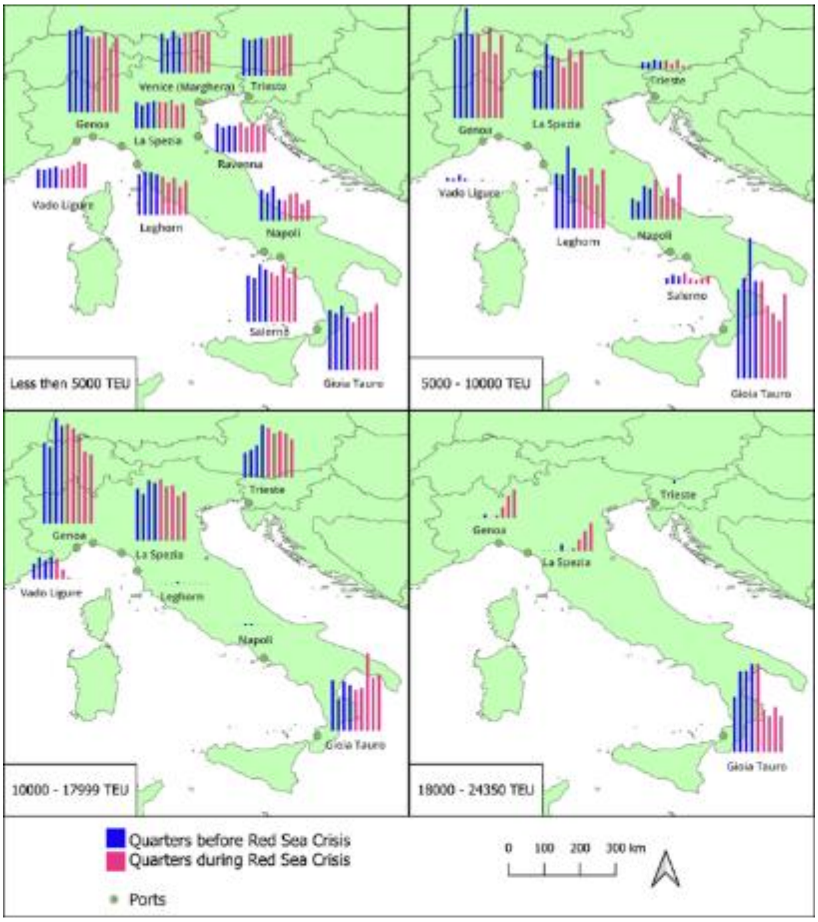

*Source: Own elaboration based on Alphaliner and port system authorities' data*

As shown in Figure 11, the size of ships calling at the Italian ports varies depending on the routes on which the services are operated. It is worth noticing that in intra-Mediterranean routes, and therefore short-range services, small vessels (less than 5,000 TEU) are mainly used. On the Gibraltar macro route, more than half of the vessels were smaller than 5,000 TEU, around 42 per cent were between 5,000 and 9,999 TEU, and a small number were between 10,000 and 17,999 TEU. In relative terms, it is this latter category that appears to have decreased the most.

Figure 11 also shows that the largest ships calling at Italian ports, both before and after the RSC, were used on routes that passed through the Suez Canal. As can be seen, the reduction in port calls on these routes was most significant for vessels with a capacity of between 5,000 and 9,999 TEU, followed by those with a capacity of under 5,000 TEU. However, more than half of the services operated by vessels larger than 10,000 TEU were introduced following the crisis, with the greatest relative increase observed in the 10,000-17,999 TEU class. These figures suggest that the new route is less cost-effective for small and medium-sized vessels.

Overall, it can be seen that, in the post-crisis period, there has been a slight increase in calls for intra-Mediterranean services and a more marked reduction in extra-regional services, particularly for the group of services that previously passed through Suez. However, the modest increase in intra-Mediterranean calls does not appear to offset the reduction in calls by the other two groups, which suggests that, overall, there has not been a significant substitution of direct extra-regional connections with feeder services to other hub ports in the region for Italian ports.

*Figure 12 Quarterly cargo capacity in ports arrived in ports divided by size of ships*




*Source: Own elaboration based on Alphaliner and port system authorities' data*

Figure 12 shows the evolution of ships' calls by vessel size. Vessels in the smallest size class called at all the Italian ports considered. For Venice and Ravenna this was the only vessel size class calling at those ports both before and after.

Furthermore, the ports along the Adriatic coast all show a slight increase in the cargo capacity of this class of ships in the quarters following the RSC, particularly Venice and Trieste.

Gioia Tauro after an initial decline recovered to normality in the third quarter, then the ships' calls increased in the final quarter of 2024.

Vado Ligure recorded an increase since the onset of the RSC, probably due to the increase in Mediterranean services, while the ports of Genoa and Leghorn, on the other hand, show a decline.

Observing the intermediate classes there is a reduction of total cargo capacity for the ships from 5,000-10,000 TEU in all the ports that received this type of ships in 2024.

For the ships sized between 10,000-17,999 TEU however the most affected ports are those of the North Tyrrhenian range. The ports of Gioia Tauro and Trieste registered instead a consistent growth. Trieste however in the last two quarters of the analysis receive less cargo capacity of this class than the year before.

Finally, the mega-vessels, i.e. containerships larger than 18,000 TEUs, are almost exclusively deployed on the Asia-Europe route, that used to transit the Suez Canal.

Given their use on hub and central ports along the East Asia-Europe route, we will take a closer look at this class of ships by analysing the number of calls and the operating carriers.

As can be seen in Figure 12, this type of ships in 2023 regularly called at only in Gioia Tauro. In 2024, on the other hand, in all quarters these ships started to call also at the ports of Genoa and La Spezia.

The port of Gioia Tauro immediately after the outbreak of the RSC drastically reduced the numbers of calls for that class.

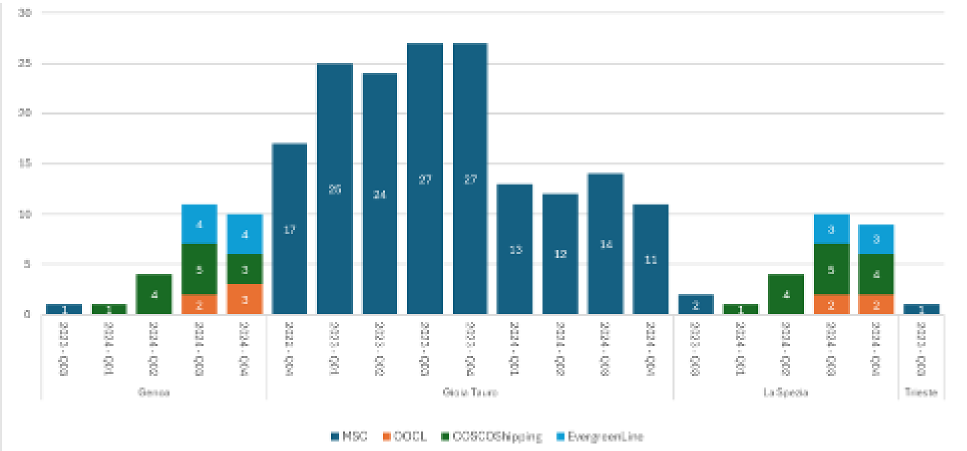
As shown in Figure 13, operating companies have changed the use of these giants of the sea in relation to Italian ports. In 2023, the only carrier to have transited ships of this class was MSC and the only ports called at were Gioia Tauro, Genoa, La Spezia and Trieste.

However, in 2024, the scenario has changed. MSC's vessels of this size called at the port of Gioia Tauro solely, more than halving the number of calls compared to 2023.

As can be seen in Figure 12, this decline for Gioia Tauro and the contemporary increase in slightly smaller ships suggests that RSC has prompted MSC to reposition these ships to different routes out of Mediterranean Sea.

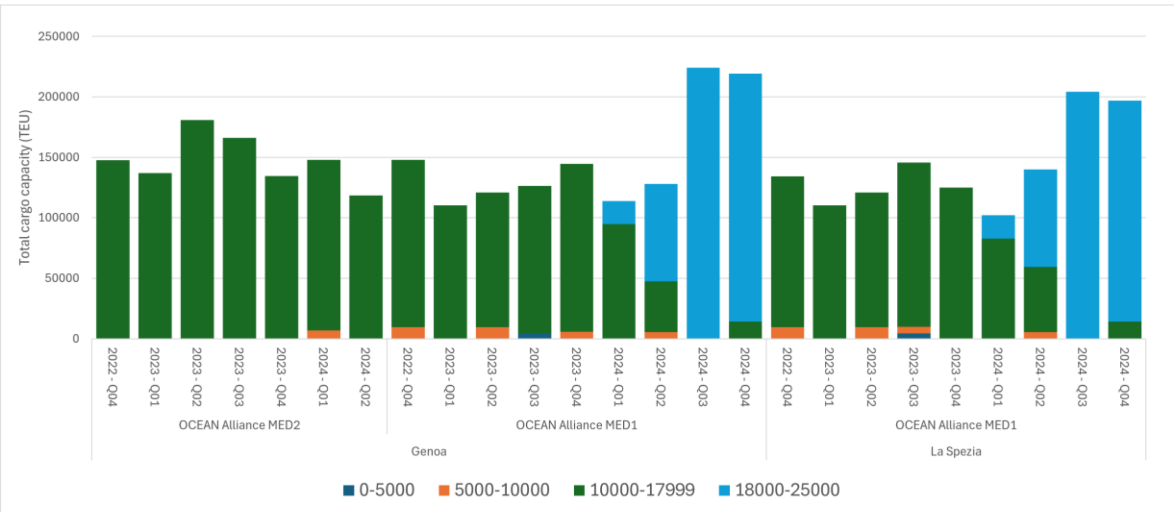
The Asian companies Cosco group (Cosco shipping lines and OOCL) and Evergreen, both belonging to the Ocean Alliance, have steadily started to call at the ports of Genoa and La Spezia since the second quarter of 2024.

*Figure 13 Number of calls of container ships larger than 18,000 TEU*




*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data*

*Figure 14 Med-Far East services of Ocean Alliance in Genoa and La Spezia with cargo capacity and vessel size.*




*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data*

These new ships in the two Ligurian ports are all part of the Alliance's MED1 Asia-Mediterranean service. As shown in Figure 14, until Q2 2024, Ocean Alliance also operated another service in the port of Genoa called MED2.

This service was closed by Ocean Alliance in Q3 2024 and the cargo capacity of the MED1 service was increased to absorb the lost cargo capacity through the predominant use of ships of the biggest class. The port of Genoa therefore recoreded an overall reduction in both cargo capacity and services, while La Spezia benefited from an increase in cargo capacity.

### 2.4.5. Carriers and Alliances in Italians ports

This Section focuses on the carriers and alliances calling at the biggest container ports in Italy. Data have been collected for the top five carriers individually and globally for the other top ten carriers and all the other smaller carriers. Figure 14 shows the total cargo capacity transited in the ports considered by the different companies.

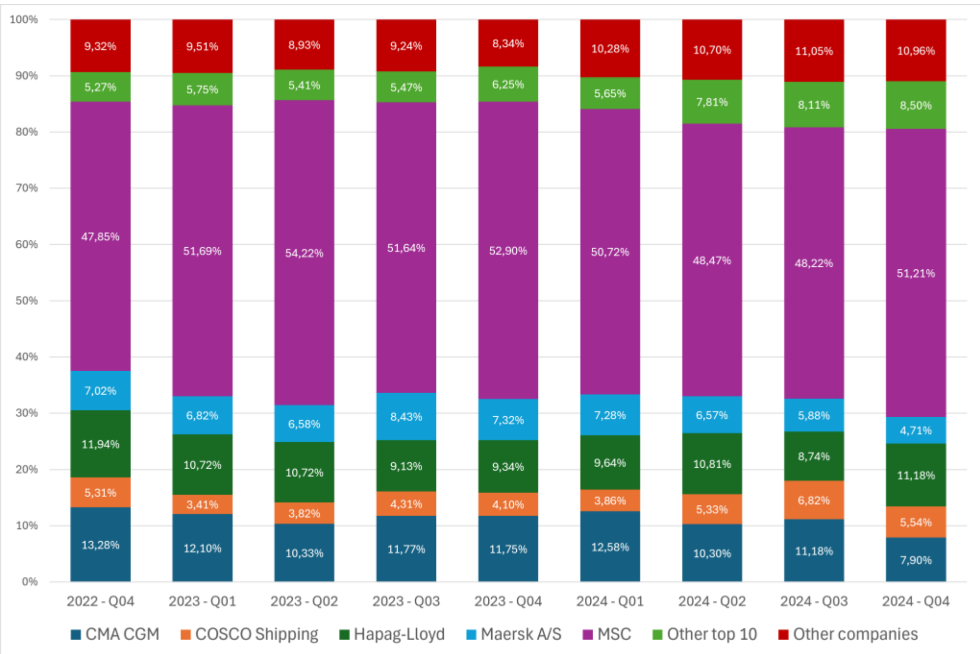
MSC is undoubtedly the leading carrier in terms of cargo capacity, accounting for nearly half of the total cargo capacity of containerships calling at the Italian ports, however, this figure recorded a decrease throughout 2024 compared to 2023.

Also Maersk registered a reduction in the last three quarters of 2024. Partly these changes could be also due to the imminent dissolution of the 2M alliance (expired in early 2025) (MSC, 2023). Out of the top five global carriers, Cosco recorded a percentage growth in 2024. The last three quarters of 2024 also saw increasing percentages for the category comprising the other top 10 carriers.

Finally, since the beginning of the crisis, the companies classified as 'other companies', i,e, those carriers out of the top 10 in terms of cargo capacity owned globally, have increased their presence in the Italian ports in all 2024 quarters.

In summary, the Red Sea crisis altered the distribution of cargo capacity among carriers serving Italian ports. Although MSC remained the dominant operator, accounting for a substantial share of the total capacity, both MSC and Maersk reduced their presence during 2024. Conversely, COSCO, the other top-ten carriers and smaller operators increased their relative shares.

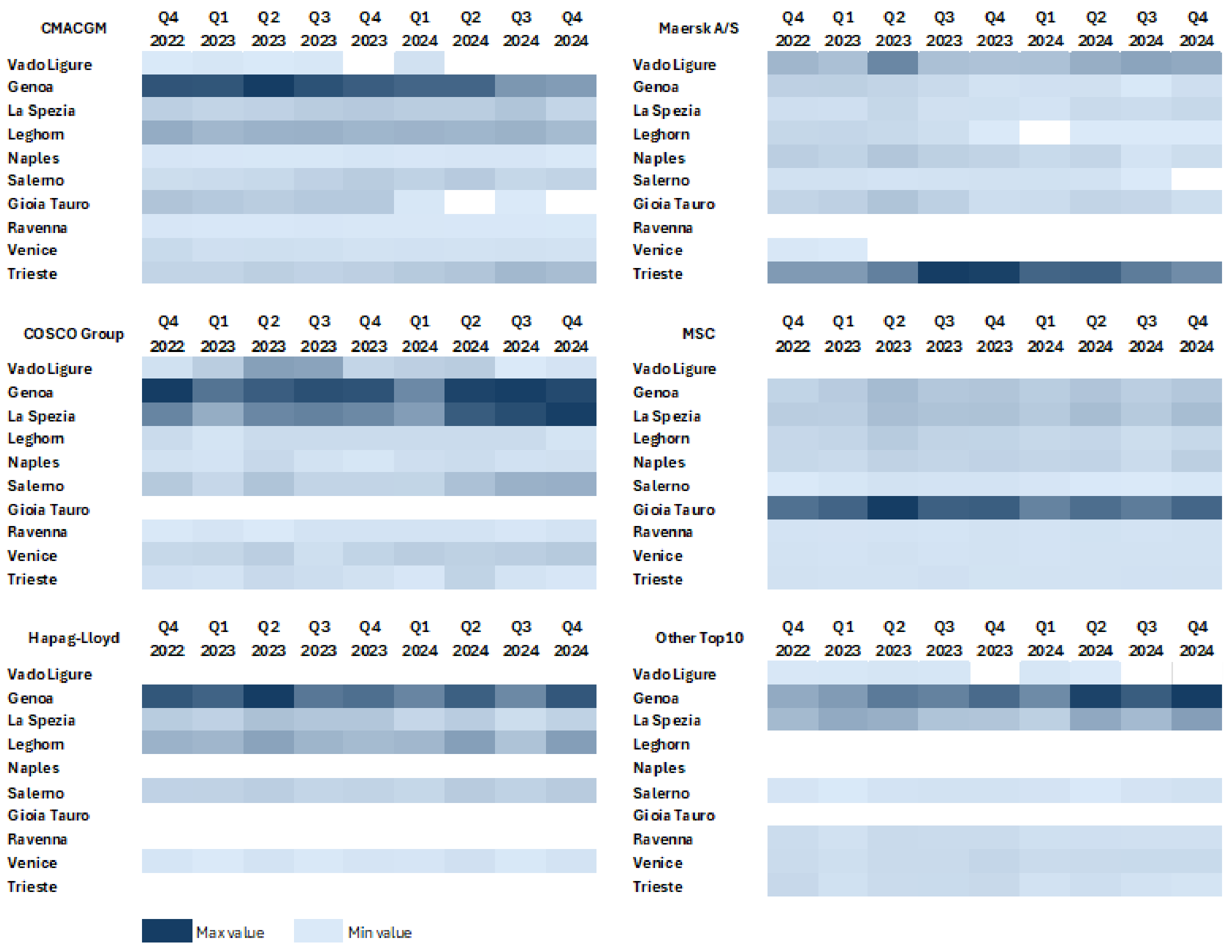
*Figure 15 Percentage of total cargo capacity in Italian ports by carriers. Carriers are classified by the first 5 biggest carriers individually, the other 5 top 10 carriers, and the other minor companies. Carriers are classified into three groups: the five largest carriers individually, carriers ranked sixth to tenth(other top 10), and all other minor carriers*




*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data*

Figure 16 shows how the main carriers allocated their capacity across Italian ports during the period under consideration.

*Figure 16 Cargo capacity distribution of Top Carriers*




*Source: Own elaboration based on Alphaliner and port system authorities' data*

CMA CGM allocates most of its freight capacity in Genoa and Leghorn. However, the former port shows a decline from the first quarter of 2024 onwards, while the latter appears more stable. In addition, in the last quarter of 2024 this company disappeared from Gioia Tauro and Vado Ligure. On the other hand, it has reinforced its presence in Trieste.

The Chinese company COSCO allocates its cargo capacity mainly in the ports of Genoa and La Spezia. In these two ports there was a marked increase in the last three quarters of 2024 after a decrease in the first quarter of the same year. In the last three quarters COSCO increased its presence also in the port of Salerno. COSCO has surprisingly seen a sharp reduction in its capacity at the Port of Vado Ligure, despite holding a 40 per cent stake in the Vado Gateway container terminal (Western Ligurian Sea Port Authority,2025).

Hapag-Lloyd mainly used the ports of Genoa, where the company has a vertical integrated terminal, the GPT Genoa Port Terminal, and the ports of Leghorn. In 2024 both ports recorded a decrease in the carrying capacity in the first and third quarters. For the German company the largest decrease since the start of the RSC can be observed in La Spezia.

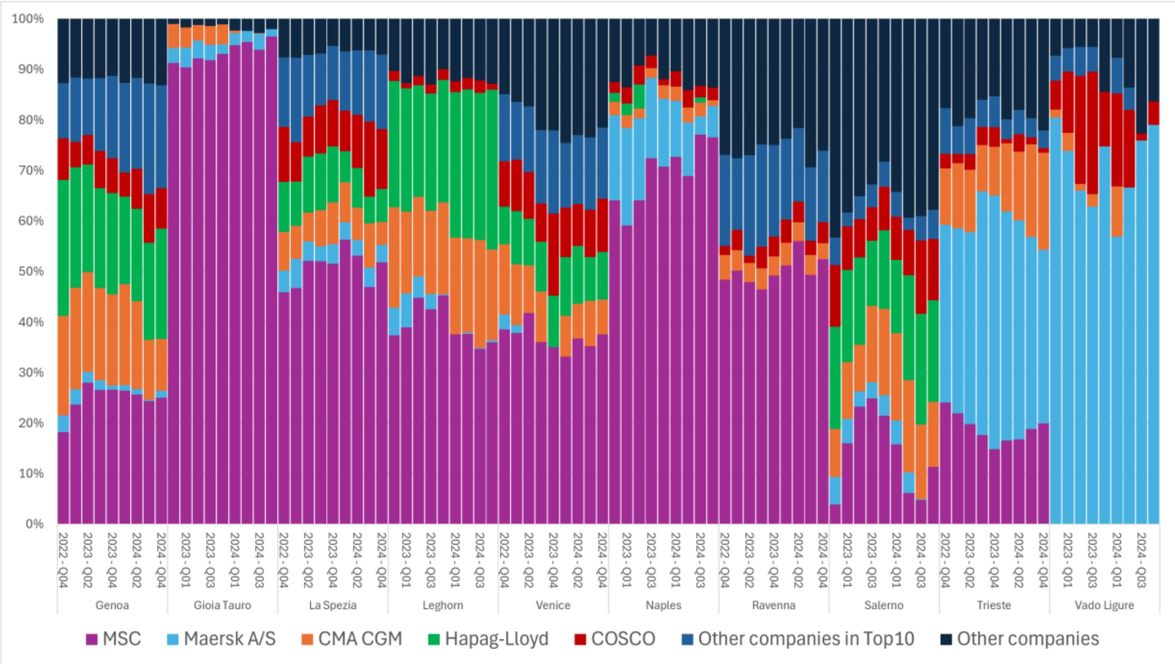
The Danish company Maersk A\S concentrates most of its cargo capacity on the ports of Trieste and Vado Ligure. In the former, however, the company reduced the vessels' capacity in all 2024 quarters and especially in the last two; while in Vado Ligure, where the company holds the controlling stake of the container terminal, it has increased over the last three quarters the vessels' capacity.

MSC concentrates most of its cargo capacity on its transshipment port of Gioia Tauro. Nevertheless, as reported above, the carrying capacity of the vessels entering the port recorded a reduction throughout 2024 (more pronounced in Q1 and Q3). If we examine these results in the light of the company's vertical integration at terminal level, we can see that this factor has not always ensured a more stable presence for the company compared with other ports. The example of Livorno shows that, despite this vertical integration, there has been a reduction in loading capacity, as well as a reduction in the percentage share of the port's total loading capacity. Furthermore, the fact that the port of La Spezia, which is itself vertically integrated by MSC, has instead shown a greater presence of the carrier suggests that geographical proximity to other integrated ports may weaken the link between port private investment by carriers and traffic routing strategies.

Where, on the other hand, this link has been strongest with the ports of Gioia Tauro and Naples, which have seen an increase in the carrier's cargo capacity.

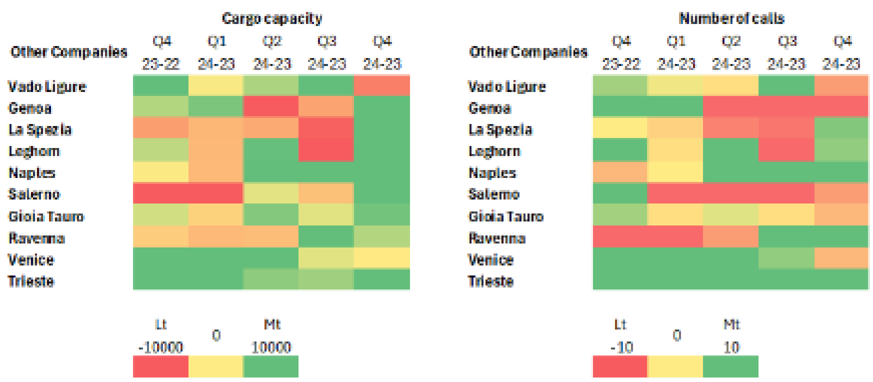
Overall, the main carriers adopted differentiated port strategies following the outbreak of the crisis. CMA CGM reduced its capacity in Genoa and withdrew from some ports while strengthening its presence in Trieste. COSCO expanded mainly in Genoa, La Spezia and Salerno, despite reducing its activity in Vado Ligure. Hapag-Lloyd continued to concentrate on Genoa and Leghorn but recorded several capacity reductions, particularly in La Spezia. Maersk shifted part of its capacity from Trieste towards Vado Ligure, while MSC maintained Gioia Tauro as its principal Italian hub despite a reduction in the capacity deployed there.

*Figure 17 Percentage of cargo capacity of the different carriers in the ports*




*Source: Own elaboration based on Alphaliner and port system authorities' data*

*Figure 18 Difference in Cargo capacity and number of calls between quarters*




*Source: Own elaboration based on Alphaliner and port system authorities' data*

As can be seen in Figure 17, MSC remains the leading carrier by cargo capacity in eight of the ten ports under analysis, Genoa, La Spezia, Leghorn, Naples, Gioia Tauro, Ravenna and Venice, despite a reduction of cargo capacity in every port, but Ravenna.

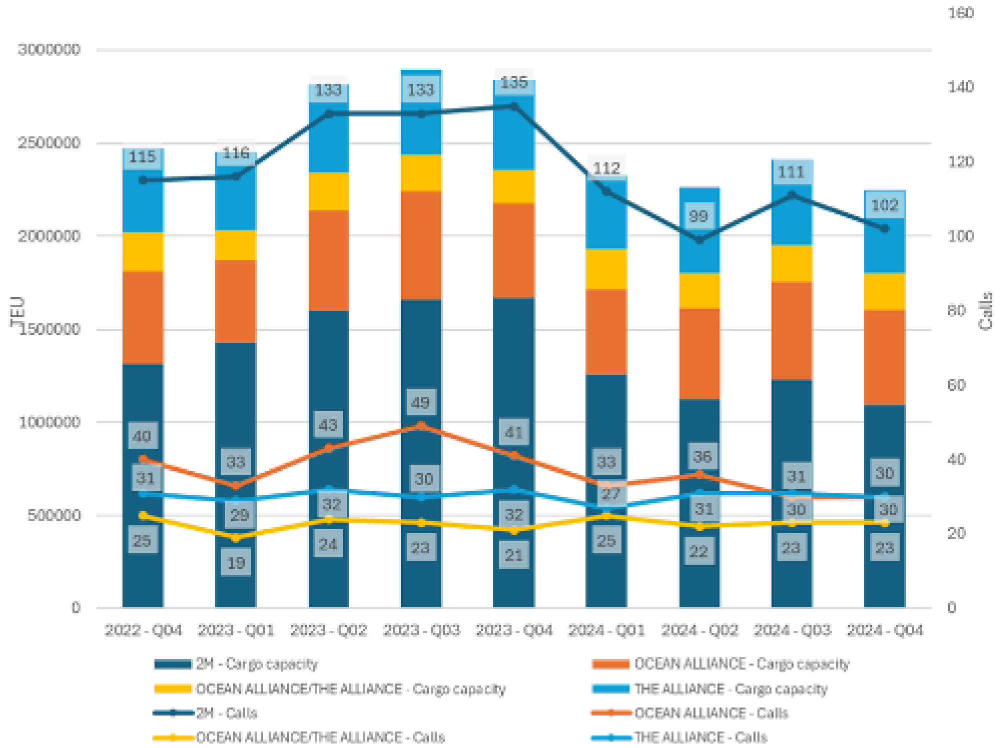
Considering the "Other Top 10" carriers, they recorded an increase in the carrying capacity of their vessels in the last three quarters of 2024 in the ports of Genoa and La Spezia, while disappeared in Vado Ligure.

Figure 17 also shows that in 5 out of 10 ports there is a dominant carrier accounting for more than 40 per cent of cargo capacity. These are Gioia Tauro, Naples, La Spezia and Ravenna, served by MSC, and Vado Ligure, served by Maersk. The same companies also dominate the ports of Livorno, Venice (MSC) and Trieste (Maersk), albeit with a slightly lower percentage, though still above 30 per cent.

Other carriers' behaviour is shown in Figure 18: Trieste recorded a growth in cargo capacity for all the quarters of the RSC and, apart from the last quarter of 2024, the same happened also in Venice.

Overall, the analysis highlights a highly concentrated market structure, with MSC remaining the leading carrier in most Italian ports despite widespread capacity reductions. Several ports continue to depend heavily on a single dominant liner operator, although smaller carriers increased their presence in Trieste and, to a lesser extent, in Venice.

*Figure 19 Cargo capacity on ports and numbers of calls of Alliances*




*Source: personal elaboration on port system authorities' data/Alphaliner*

Finally, we observed the behavior of the maritime alliances. Figure 19, which depicts the changes in cargo capacity and the number of calls of liner services operated by the strategic alliances, shows that in 2024 the total carrying capacity of the alliances compared to the previous year's quarters decreased. The alliance that has decreased the most is 2M, which also reduced the number of calls in Q2, Q3 and Q4 of 2024 compared to 2023.

Table 8 shows how services operated by alliance have been affected by the RSC, but only one OCEAN Alliance service (MED2) has been erased (the effects of which have already been analysed above).

Has already been previously described analysing the megaships, 2M halved the number of calls probably reducing the frequence of the service AE11/Jade in the Med-Far East route. It should also be noted that a reduction in the number of port calls has been seen on 2M's Mediterranean-North America services, which

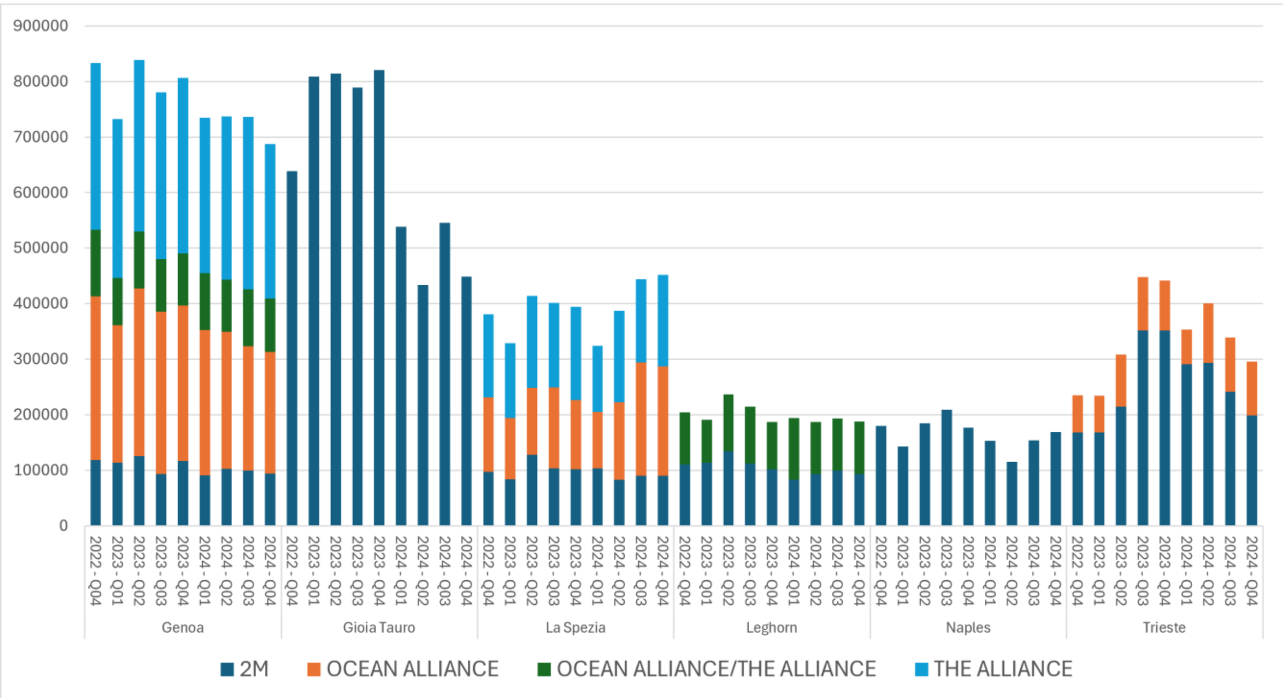
have not been directly affected by the RSC, albeit to a far lesser extent than the Mediterranean-Far East services.
Figure 20 shows that the ports to which the alliances direct the most cargo, in terms of cargo capacity, are Genoa, La Spezia, Gioia Tauro and Trieste. The first two ports are the only ones with the presence of all three Alliances. In Leghorn and Genoa there is also a coordinated service between Ocean Alliance and The Alliance which continued during the RSC quarters.

*Table 8 Services of Alliances in Italian ports*

| Alliances | Services | Q4-2022 | Q1-2023 | Q2-2023 | Q3-2023 | Q4-2023 | Q1-2024 | Q2-2024 | Q3-2024 | Q4-2024 |
|---|---|---|---|---|---|---|---|---|---|---|
| **2M** | 2MagreementAsiaMedAE11/Jade* | 20 | 25 | 25 | 25 | 26 | 13 | 12 | 13 | 11 |
| | 2MagreementAsiaMedAE12/Phoenix* | 11 | 11 | 14 | 23 | 23 | 20 | 19 | 17 | 13 |
| | 2MagreementTransatlanticTA5/MEDUSEC** | 52 | 48 | 55 | 47 | 50 | 40 | 38 | 46 | 44 |
| | 2MagreementTransatlanticTA6/MEDGULF** | 32 | 31 | 39 | 38 | 36 | 39 | 30 | 34 | 34 |
| **OCEAN Alliance** | OCEANAllianceAsiaMedserviceMED1* | 21 | 17 | 20 | 27 | 21 | 16 | 17 | 21 | 21 |
| | OCEANAllianceAsiaMedserviceMED2* | 10 | 9 | 12 | 11 | 9 | 11 | 8 | | |
| | OCEANAllianceAsiaMedserviceMED5* | 9 | 7 | 11 | 11 | 11 | 6 | 11 | 9 | 9 |
| **OCEAN Alliance/ THE Alliance** | OCEANAlliance/THEAlliance MedUSECjointservice (Amerigo/AL6/ATM1)** | 25 | 19 | 24 | 23 | 21 | 25 | 22 | 23 | 23 |
| **THE Alliance** | THEAllianceAsiaMedserviceMD1* | 10 | 10 | 9 | 10 | 10 | 10 | 10 | 10 | 9 |
| | THEAllianceAsiaMedserviceMD2* | 21 | 19 | 23 | 20 | 22 | 17 | 21 | 21 | 21 |

*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data. *Suez **Gibraltar*

*Figure 20 Total cargo capacity on ports by quarter divised per Alliances*




*Source: Own elaboration based on Econdb, Alphaliner and port system authorities' data*

*Table 9 Difference in number of calls between quarters of services in alliances*

| Port | Route | Diff. between Quarters | 2M | | Ocean Alliance | | Ocean Alliance / The Alliance | | The Alliance | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cargo capacity | Calls | Cargo capacity | Calls | Cargo capacity | Calls | Cargo capacity | Calls |
| Genoa | Med - Far East | Q04 23-22 | | | **-16156** | **-1** | | | 16625 | 0 |
| | | Q01 24-23 | | | 14593 | 0 | | | **-6226** | **-1** |
| | | Q02 24-23 | | | **-55281** | **-4** | | | **-14933** | 0 |
| | | Q03 24-23 | | | **-68281** | **-9** | | | 9631 | 2 |
| | | Q04 24-23 | | | **-59921** | **-9** | | | **-38531** | **-2** |
| | Med - North America | Q04 23-22 | **-1038** | 0 | | | **-25988** | **-3** | | |
| | | Q01 24-23 | **-22755** | **-2** | | | 16813 | 2 | | |
| | | Q02 24-23 | **-22584** | **-2** | | | **-8750** | **-1** | | |
| | | Q03 24-23 | 5638 | 0 | | | 8488 | 0 | | |
| | | Q04 24-23 | **-23013** | **-3** | | | 2438 | 1 | | |
| Gioia Tauro | Med - Far East | Q04 23-22 | 170436 | 6 | | | | | | |
| | | Q01 24-23 | **-278266** | **-11** | | | | | | |
| | | Q02 24-23 | **-302044** | **-15** | | | | | | |
| | | Q03 24-23 | **-251364** | **-10** | | | | | | |
| | | Q04 24-23 | **-358582** | **-15** | | | | | | |
| | Med - North America | Q04 23-22 | 11645 | 3 | | | | | | |
| | | Q01 24-23 | 7845 | 1 | | | | | | |
| | | Q02 24-23 | **-78088** | **-8** | | | | | | |
| | | Q03 24-23 | 7685 | 2 | | | | | | |
| | | Q04 24-23 | **-13164** | **-3** | | | | | | |
| La Spezia | Med - Far East | Q04 23-22 | | | **-9236** | 0 | | | 17815 | 1 |
| | | Q01 24-23 | | | **-8163** | **-1** | | | **-15757** | **-1** |
| | | Q02 24-23 | | | 19137 | 1 | | | **-260** | 0 |
| | | Q03 24-23 | | | 58355 | **-2** | | | **-2138** | 0 |
| | | Q04 24-23 | | | 71875 | 1 | | | **-3155** | 0 |
| | Med - North America | Q04 23-22 | 4643 | 1 | | | | | | |
| | | Q01 24-23 | 19589 | 2 | | | | | | |
| | | Q02 24-23 | **-45422** | **-5** | | | | | | |
| | | Q03 24-23 | **-13754** | **-1** | | | | | | |
| | | Q04 24-23 | **-11580** | **-1** | | | | | | |
| Leghorn | Med - North America | Q04 23-22 | **-8666** | **-1** | | | **-8488** | **-1** | | |
| | | Q01 24-23 | **-31368** | **-2** | | | **18278** | 4 | | |
| | | Q02 24-23 | **-40603** | **-4** | | | **-8750** | **-1** | | |
| | | Q03 24-23 | **-13144** | **-1** | | | **-875** | **-1** | | |
| | | Q04 24-23 | **-8758** | **-1** | | | 48835 | 1 | | |
| Naples | Med - North America | Q04 23-22 | **-2794** | 2 | | | | | | |
| | | Q01 24-23 | 10602 | 2 | | | | | | |
| | | Q02 24-23 | **-68861** | **-7** | | | | | | |
| | | Q03 24-23 | **-55112** | **-6** | | | | | | |
| | | Q04 24-23 | **-7731** | **-2** | | | | | | |
| Trieste | Med - Far East | Q04 23-22 | 183515 | 13 | 22610 | 2 | | | | |
| | | Q01 24-23 | 122593 | 8 | **-3630** | **-1** | | | | |
| | | Q02 24-23 | 79077 | 4 | 12976 | 0 | | | | |
| | | Q03 24-23 | **-110727** | **-8** | 2713 | **-1** | | | | |
| | | Q04 24-23 | **-153204** | **-11** | 7308 | **-2** | | | | |

*Source: Own elaboration based on Alphaliner and port system authorities' data. Negative data highlighted in bold*

Table 9 shows how Alliance services have changed according to the routes sailed. The Port of Genoa recorded a decrease in both the number of calls and capacity for the Ocean Alliance services for the Med-Far East services, while The Alliance registered a slight increase in capacity in all quarters except Q1 2024. On the Med-North America route, on the other hand, there was slight decrease in capacity and number of calls by 2M.

Gioia Tauro showed the strongest reduction in Med Far East services. The 2M Alliance, after an initial increase in Q4 2023, drastically reduced the cargo capacity and calls on this route. By contrast, the Med-North America route does not undergo any major changes, despite a more pronounced reduction in Q2 2024 in both cargo capacity and calls. For La Spezia on the Med-Far East route, the situation seems to be quite stable for both alliances that use to call at the port. There seems to be a slight increase in cargo capacity in the last three quarters of 2024. Also, it was quite stable for 2M on the Med-North America route, although with a reduction in calls in the last three quarters.

Finally, in Trieste services offered by 2M, after the onset of the RSC, initially increased in both capacity and calls, however, a sharp decline in the trend is observable in the last two quarters of 2024. On the one hand, this forms part of the process of penalising Adriatic ports brought about by the RSC; on the other, it is due to the imminent dissolution of the 2M alliance between MSC and Maersk

In summary, maritime alliances responded to the Red Sea crisis in the short/mid-term primarily by reducing capacity and service frequency. The most substantial contraction concerned the 2M Alliance, whose capacity and number of calls declined markedly during the last three quarters of 2024, particularly on the Mediterranean-Far East route. Ocean Alliance closed the MED2 service but partly compensated for this loss by increasing the capacity deployed on MED1 through larger vessels.

Taken together, the findings show that the Red Sea crisis accelerated a broader reorganisation of carrier and alliance networks in Italian ports. The response involved lower number of calls (and probably in consequence the frequency of the services), changes in vessel capacity, selective redistribution of calls among ports and a greater concentration of cargo capacity on specific services. Although Italian ports retained an important role in the Mediterranean network, their position on major Far East routes weakened, while ports capable of attracting regional services, alternative operators or larger vessels proved comparatively more resilient.

## 2.5 Conclusions

This study examined the impact of the Red Sea crisis on Italian ports. The first part of the analysis showed that, at the national level, the number of port calls decreased, while container traffic did not decline; on the contrary, it increased by 5.6 per cent.

Taken together, these two trends resulted in a greater concentration of cargo volumes on fewer vessel calls in all ports except Trieste. From an operational perspective, this phenomenon implies higher workload peaks in ports and probably contributed to longer average vessel dwell times in eight out of ten ports.

The analysis highlights that the effects of the crisis were not uniform across ports. A clear geographical pattern appears to emerge: Adriatic ports experienced the most severe effects of the crisis in terms of container throughput, whereas Tyrrhenian ports recorded the greatest traffic growth during the crisis, with Livorno representing an exception. However, the shift-share analysis showed that, despite an increase in container handling, the ports of Genoa and Salerno lost market share after the outbreak of the crisis.

The analysis also shows that the crisis effectively caused the marginalisation of most Italian ports on extra-regional routes, with a reduction in the number of services. This reduction had the greatest impact on services that had previously transited the Suez Canal. As noted in Section 4.3, the results of the shift-share analysis show that all ports with an increase in market share also increased the number of intra-Mediterranean services. This suggests that the increased centrality of intra-Mediterranean services may have been a competitive factor for these ports. Among them, Gioia Tauro, which increased both intra- and extra-regional services, especially within the "Gibraltar" group, recorded the best performance and appears to have benefited from the crisis.

Moreover, the reduction in the number of services contributed to a reduction in the number of operators providing extra-Mediterranean services, thereby increasing ports' dependence on a narrower set of carriers for container traffic.

Finally, with regard to the effects of the crisis on alliances, two main findings emerge. First, 2M recorded a reduction in deployed cargo capacity. Second, the crisis led Ocean Alliance to discontinue the Med–Far East MED2 service at the port of Genoa. This service was replaced by increasing capacity on the MED1 service, which calls at Genoa and La Spezia, through the deployment of vessels exceeding 18,000 TEU. This reduced the frequency of calls on the Med–Far East route from Genoa while increasing cargo capacity on the route to the port of La Spezia. It can therefore be argued that the crisis triggered by the Houthi attacks on Red Sea shipping at the end of 2023 initiated a process of reorganisation in the sector. Although this process was initially aimed at mitigating the effects of the only available alternative route, in terms of longer sailing times and higher operating costs, it subsequently led shipping companies to rethink the structure of their service networks, both independently and through strategic alliances.

These two processes affected Italian ports, which currently appear to be experiencing a reduced role in the main international shipping routes connecting Europe and the Far East, while at the same time strengthening their relative position within the Mediterranean Sea.

These trends and processes are still ongoing. Although the Houthis have officially declared an end to attacks on commercial vessels following the ceasefire agreements of October 2025, at the time of writing this thesis, traffic in the Red Sea remains well below pre-crisis levels. The major shipping companies continue to use the route via the Cape of Good Hope for the Europe-Far East route.  This will certainly provide an opportunity in the medium to long term to observe how the reorganisation of maritime services has settled into this ‘new normal’.

# 3. Chapter 2: Hub dependency in Mediterranean Sea, the case of Italian Ports

## 3.1 Introduction

This chapter addresses the relatively under-researched topic of hub dependency in the Mediterranean Sea maritime transport literature. The concept emerged in the context of studying maritime networks and the evolution of port geographies, particularly in developing countries where the marginalisation and peripheralisation of ports has been widely observed (Airriess, 1989; Wang, 1998; Iheduru, 1996; Brodin, 2003).

Early contributions to this field examined how structural economic constraints, political transitions and uneven infrastructural development affected the position of ports within global and regional maritime networks. These studies have highlighted the tendency for maritime flows to become increasingly concentrated in a limited number of dominant ports while secondary ports progressively lose direct access to international shipping routes.

Hub dependency was first systematically formalised using quantitative methodologies by Ducruet (2008), who applied network analysis to a country isolated from international trade, such as North Korea. Within this analytical framework, hub dependency refers to a condition in which certain ports, or even entire national maritime systems, become increasingly dependent on hub ports in order to participate in global maritime trade.

This process is generally associated with a reduction in direct port-to-port connections, resulting in the concentration of inbound and outbound maritime flows. While the number of indirectly connected ports may increase, overall dependence on a limited set of maritime nodes intensifies. These nodes then assume a dominant role in the trade of a given region, thereby increasing the structural vulnerability of a port's, region's or country's maritime trade network (Ducruet et al., 2010; Xu and Xia, 2017).

Although the study of hub dependency has primarily focused on developing countries or nations subject to political and economic constraints, broader transformations in global maritime transport, particularly in container shipping, suggest that similar dynamics may now characterise a wider range of port systems. Container shipping has evolved towards a hub-and-spoke organisational model driven by economies of scale, growth in vessel size, and network optimisation strategies (Ducruet and Notteboom, 2012). From this perspective, it could be argued that containerised maritime transport has contributed to the emergence of a generalised form of hub dependency affecting many smaller ports, as well as those occupying low to medium positions within global port hierarchies.

Since the mid-1990s, container maritime transport networks have increasingly adopted a hub-and-spoke structure, particularly within container shipping systems (Fleming and Hayuth, 1994; Notteboom and Rodrigue, 2005; Ducruet and Notteboom, 2012). This organisational model has reshaped the spatial configuration of maritime networks, centralising traffic flows in a limited number of highly connected hub ports.

The “hub-and-spoke” model is not unique to maritime transport; rather, it is a concept related to network configuration in itself. It describes a configuration in which one or a small number of nodes concentrate a large proportion of connections and function as central intermediaries, linking multiple smaller nodes that would otherwise lack direct access to the network (Rodrigue, 2024). In maritime transport, this model has become increasingly dominant as a result of structural changes in shipping operations and logistics organisation.

The emergence and consolidation of hub ports in container shipping is closely linked to the development of economies of scale, which are driven by the continuous increase in vessel size, a process often described as the 'race to gigantism' (Cullinane and Khanna, 2000). Vessel upsizing has encouraged the concentration of cargo on fewer, larger ships operating on routes characterised by high traffic volumes. To ensure economic viability, these services have progressively reduced the number of port calls, favouring ports capable of handling large volumes of containerised cargo and offering high levels of operational efficiency (Hayuth, 1981). Consequently, maritime flows have become increasingly concentrated in ports occupying central positions within the global maritime network, commonly referred to as hub ports.

The longer port times required for loading and unloading ultra-large container vessels have further reinforced this process, with shipping lines seeking to minimise operational delays by limiting calls to a select number of well-equipped ports. At the same time, this evolution has stimulated the development of feeder services, operated by smaller vessels, which connect hub ports to secondary ports that are not served directly by mainline vessels (Cullinane and Khanna, 2000).

This reconfiguration of maritime networks is also closely related to the increasing concentration of the container shipping market in the hands of a small number of major carriers. Liner shipping networks form the backbone of global container transport and are now managed by a relatively small group of operators who can sustain the high fixed costs associated with large vessels. These operators design their service networks based on capacity optimisation strategies and alliance agreements, which enable them to jointly manage supply and respond to transport demand across different regions. Additionally, vertical integration processes, which have led shipping lines to acquire or control container terminals in recent decades, have become a further factor in shaping the structure of maritime service networks (Notteboom et al., 2017).

Hub ports may primarily function as transshipment ports, where containers carried by large vessels are transferred onto smaller ships. Pure transshipment ports differ from gateway ports in that they do not rely on a significant local hinterland. However, hub ports may exhibit varying degrees of specialisation, with some combining transshipment functions with gateway roles linked to inland markets (Notteboom, 1997; Arvis et al., 2018).

This chapter will address the topic of hub dependency and the structure of hub ports in the Mediterranean by responding to the following research questions: Has the development of hub ports in the Mediterranean reduced the centrality of Italian gateway ports? Which ports become more dependent on hub ports, and which have maintained more autonomy? Has the development of hub ports in the mediterranean affected the vulnerability of the maritime network of Italian ports? Is there some evidence from the recent crisis?

This part of the text is divided into three sections: The first section presents a literature review on the subject. It will begin by analyzing the hub-and-spoke concept in maritime transport and in the Mediterranean. It will then examine the use of network analysis to analyze maritime networks, hub-and-spoke structures, and hub dependency. Finally, a brief literature review on methods for analyzing the vulnerability of maritime networks will be presented. The second section will outline the data and methodologies used, and the third section will present the results of the analysis.

The analysis focuses on the 14 leading Italian container ports by TEU traffic over the period 2000–2023 and observe the evolution of the hub and spoke structure on Mediterranean ports. Network analysis measures, such as betweenness, eigenvector, and closeness centrality, were calculated for Mediterranean ports in order to assess their levels of centrality and peripherality over the period under review. These measures were then examined in relation to the percentage of hub dependency using Spearman's correlation coefficient, with the aim of determining whether a relationship exists between these two dimensions.

## 3.2 Literature review

### 3.2.1. Hub and spoke model in maritime container

The concept of hub ports has become central to understanding the organisation of contemporary maritime transport networks. The increasing scale of container shipping operations, the expansion of global liner services and the widespread adoption of hub-and-spoke logistics models have reinforced the strategic role of ports that specialise in transshipment activities. In this context, a growing body of literature has examined the emergence, functions and selection criteria of hub ports within global maritime networks. The following studies provide key insights into the factors shaping hub port development, their operational role within shipping networks and the competitive dynamics that characterise the global container transport system. Fleming and Hayuth (1994) provide empirical evidence that centrality and intermediacy are key characteristics of transport hubs. Their analysis covers both the North American airport system and the global organisation of containerised maritime transport. The authors demonstrate how shifts in the geography of production and consumption, together with the adoption of containerisation and the development of round-the-world maritime services by shipping lines, have significantly reshaped the structure of the global port hierarchy. As a result of these transformations, ports with strong transshipment functions, such as Singapore, have been able to attain leading positions within the global maritime network.

In this context, the authors emphasise that intermediacy within round-the-world services plays a crucial role in the locational choice of hub ports, distinguishing them from traditional load centres, where traffic concentration is primarily linked to a specific hinterland. Hub ports therefore emerge as nodes whose strategic importance derives mainly from their position within transport networks rather than from locally generated cargo. Fleming and Hayuth (1994) also illustrate the emergence of hub ports in the Mediterranean through the development of the Port of Valletta project in Malta. Moreover, their analysis highlights the role of political factors in shaping hub port development. For instance, the Iran-Iraq War led to a substantial increase in traffic at Port Rashid in Dubai, facilitating its rise as a major hub port at the expense of other Gulf ports, a trend that persisted even after the conflict ended. Overall, the authors argue that intermediacy should be understood as a temporary and somewhat artificial condition, largely shaped by the operational organisation of transport networks.

Building on these early insights into the network-based nature of hub ports, later studies have examined how shipping service networks themselves have evolved around hub-and-spoke configurations. McCalla et al. (2005), for example, analyse changes in maritime service networks created by shipping alliances in the Caribbean region between 1994 and 2002. Their study identifies the growing dominance of hub ports over other ports and traces key trajectories in traffic flows and network development. The Caribbean basin is recognised as a strategic crossroads for major global shipping routes, linking north-south flows from South America with east-west routes via the Panama Canal that connect Asia with the east coast of North America and Western Europe.

To assess these changes, McCalla et al. (2004) evaluate network characteristics using the beta value (the ports-to-connections ratio), which measures redundancy and connectivity. Over the study period, they observe that service networks became progressively simpler, with fewer services, fewer ports served and fewer connections, resulting in lower redundancy. While regional and global services declined, local services increased, reflecting the consolidation of a hub-and-spoke network structure. Within this evolving system, the development of hub ports is influenced by several factors, including geographic location, the level of transshipment activity, governance quality and the role of shipping alliances. Smaller carriers generally operate more local and regional services, and only a limited number have been integrated into the hub-and-spoke structures dominated by major alliances.

The operational importance of hub ports within these network configurations is further emphasised by Notteboom (2012), who highlights their role in consolidating and redistributing container flows. Hub ports function as nodes that link two or more liner services within hub-and-spoke networks, enabling the efficient organisation of global shipping operations. These networks rely on both mainline-feeder operations and relay activities, the latter referring to the transshipment of cargo between vessels of similar size at intermediate hub terminals.

Most intermediate hubs are located along the main global shipping corridor, commonly referred to as the equatorial round-the-world route, which encompasses regions such as the Caribbean, Southeast Asia, East Asia, the Middle East and the Mediterranean. Ports located near critical maritime chokepoints, including the Strait of Gibraltar, the Suez Canal, the Panama Canal and the Malacca Strait, often become focal nodes that stimulate the development of transshipment and interlining activities. In this context, the selection of appropriate hub ports becomes a key strategic decision for shipping lines.

Indeed, Lirn et al. (2003, 2004) emphasise that choosing suitable transshipment hubs is fundamental for the organisation of maritime carrier networks. Effective hub selection allows shipping companies to improve operational efficiency, achieve higher vessel load factors along main routes, control operating costs and ensure schedule reliability. However, the reliance on transshipment activities also introduces new forms of vulnerability and volatility within port systems.

This aspect is highlighted by Notteboom et al. (2019), who analyse 61 ports in Northern Europe and the Mediterranean and classify them as gateway, mixed or hub ports based on their container transshipment volumes. Their findings show that hub ports tend to experience greater traffic volatility, mainly due to their dependence on a limited number of terminal operators, the strategic network decisions of shipping lines and the highly competitive nature of the transshipment market.

Against this background, a growing body of research has focused on the criteria used by shipping lines when selecting transshipment hub ports and the implications of these choices for network structure and regional competition. Kavirathna et al. (2018), for instance, examine hub ports surrounding the Bay of Bengal and demonstrate that hub selection is influenced by a combination of location advantages, nautical accessibility, terminal efficiency, service frequency, connectivity and cost-related factors. They also highlight how the increasing size of container vessels, combined with infrastructural constraints in smaller ports, has reinforced the adoption of hub-and-spoke networks in liner shipping (Ducruet and Notteboom, 2012).

As hub-and-spoke systems expand, competition among hub ports intensifies, particularly in regions that are not directly served by mainline vessels. In the Bay of Bengal region, for example, Colombo, Singapore, Port Klang and Tanjung Pelepas compete to attract feeder traffic. Nevertheless, Ducruet et al. (2011) argue that, despite the development of some secondary ports, global maritime networks remain structurally polarised around a limited number of major hub ports that display strong resilience to internal and external competitive pressures.

Port selection dynamics also vary significantly across regions. Gohomene et al. (2016) show that in West Africa a larger potential hinterland size does not necessarily translate into greater port attractiveness, while Dyck and Ismael (2015) argue that the increasing number of competing ports has made hub selection decisions more complex for shipping lines. Taken together, these studies suggest that hub port development is shaped by both network-level constraints, geographical position, and region-specific competitive conditions, reinforcing hierarchical and polarised structures within global container shipping networks.

More specifically, several studies highlight that deviation time and vessel diversion costs are key parameters in the design of liner service networks based on transshipment logic (Kavirathna et al., 2018). Consequently, the strategic location of transshipment hubs within the global maritime network is widely considered a primary selection criterion, particularly with regard to proximity to major shipping lanes and network centrality (Kavirathna et al., 2018; Rodrigue and Notteboom, 2010).

In addition to these spatial factors, a range of operational and institutional attributes also influence port choice. Nautical accessibility and maritime connectivity play an important role (Saeed and Aaby, 2013; Salem and El-Sakti, 2014), as does the political stability of the region in which the port is located, particularly in developing contexts (Gohomene et al., 2016). From an operational perspective, transshipment hubs must ensure short container dwell times in order to remain competitive (Chu and Huang, 2005). Shipping lines therefore evaluate a wide set of performance indicators, including infrastructure capacity, berth and yard adequacy, equipment availability, and the efficiency and quality of cargo handling and technical-nautical services (Chinonye et al., 2006; Sedigheh, 2015; Wang and Yeo, 2019). Finally, ocean carriers are highly sensitive to the monetary costs associated with port calls, such as terminal handling charges, anchorage costs and tariffs for pilotage, mooring and related nautical services, which often play a decisive role in the selection of transshipment hubs (Sedigheh, 2015).

### 3.2.2. Hub ports in mediterranean sea

The emergence of hub ports has been particularly significant in the Mediterranean region, where the strategic position between major east-west maritime routes has favoured the development of transshipment activities and hub-and-spoke network configurations. Over the past decades, several studies have examined the evolution of Mediterranean port systems, focusing on the factors driving hub port development, the competitive dynamics among ports, and the implications of shipping network restructuring.

A large number of hub ports have emerged in the Mediterranean region since the late 1990s. In a seminal study, Notteboom (1997) analysed the distribution of container traffic in European ports in order to evaluate the effectiveness of different port development models. The author observes that the development of new container ports in the Mediterranean has been closely linked to the emergence of hub ports located near the round-the-world (RTW) shipping route between the Suez Canal and the Strait of Gibraltar. These ports have progressively concentrated traffic flows and benefited from economies of scale.

Consistent with this spatial perspective, Zohil and Prijon (1999) identify a strong correlation between a port's distance from main shipping lanes and its share of total transshipment traffic. Their analysis shows that transshipment costs increase when hub ports are located far from the final destination of cargo. Furthermore, they conclude that transshipment volumes in a given port are influenced by traffic volumes handled by adjacent ports, emphasising the relational and network-based nature of transshipment activity.

Building on the analysis of traffic concentration dynamics, Fageda (2000) examines competition among Mediterranean ports in the container sector in their attempt to become load centres and acquire dominant positions within the regional system. Using the Gini coefficient, Lorenz curves and shift-share analysis, the study demonstrates that hub ports experienced higher growth rates in traffic consolidation. These ports emerged as Mediterranean load centres primarily due to economies of scale driven by shippers and their proximity to the main east–west trade routes.

While these studies mainly focus on port location and traffic distribution, other contributions emphasise the role of shipping companies and alliances in shaping maritime networks. McCalla et al. (2004), for instance, analyse the strategies of shipping lines and alliances through a comparative study of maritime networks in the Caribbean and Mediterranean regions between 1994, prior to the formation of major container shipping alliances, and 2002. Their findings indicate that the Mediterranean maritime network was more developed and exhibited greater stability over time than the Caribbean network. In addition, the Mediterranean displayed a higher level of network density at the intra-regional scale. The study also highlights the specific role played by strategic alliances within maritime networks. Although alliances were crucial for inter-oceanic services, at the time of the study most connections were not operated by alliances (only about 15% in the Mediterranean in 2002).

More recent research has further explored the structural characteristics and vulnerabilities of Mediterranean hub ports. Notteboom et al. (2019) analyse a sample of 61 Northern European and Mediterranean ports and classify them as gateway, mixed or hub ports according to their container transshipment traffic volumes. Their results show that hub ports tend to experience greater traffic volatility, largely due to their dependence on a limited number of terminal operators and on the strategic network decisions of shipping lines, as well as the highly competitive environment of the transshipment market.

Further insights into the economic performance of transshipment hubs are provided by Notteboom et al. (2023), who investigate the relationship between operational productivity and financial performance in Italian container ports. Their empirical analysis compares pure transshipment hubs with gateway terminals and reveals that, although sea-sea transshipment accounts for a substantial share of global container throughput, pure transshipment terminals tend to experience higher traffic volatility and significantly lower profitability and cash-flow generation than gateway or mixed terminals, even when productivity levels are comparable. During the study period, Italian transshipment hubs faced intense competition from major Mediterranean ports such as Valencia, Algeciras, Barcelona, Tangier Med and Malta Freeport. The findings suggest that shipping lines' involvement in pure transshipment hubs is primarily driven by network optimisation and operational considerations rather than by direct financial returns.

The broader evolution of intermediate hub regions in container shipping is analysed by Notteboom (2012), who compares relay and interlining operations along the Suez Canal route and the Cape of Good Hope route. The study shows that several intermediate hub ports, including Freeport, Salalah, Tanjung Pelepas, Gioia Tauro, Algeciras, Taranto, Cagliari, Damietta and Malta, have emerged since the mid-1990s as key nodes for bundling container cargo through hub-and-spoke networks based on mainline–feeder and relay operations. Most of these hubs are located along the global beltway or equatorial round-the-world route, often in proximity to major maritime chokepoints such as the Straits of Gibraltar, the Suez Canal, the Panama Canal and the Malacca Straits. By analysing distance, transit time and travel costs, Notteboom (2012) also demonstrates that the long-term dependency of several major European hubs on the Suez route is not guaranteed under conditions of rising bunker costs, slow steaming practices, vessel upsizing and the increasing importance of South–South trade flows.

Other studies have explored the broader institutional and geopolitical factors shaping Mediterranean port development. Ferrari et al. (2006), for example, examine how the enlargement of the European Union and the restructuring of Mediterranean maritime transport systems could influence port development trajectories, potentially fostering a process of cargo deconcentration among ports. Focusing on gateway ports in both the eastern and western Mediterranean, the authors identify strategic options, such as logistics integration, improvements in operational efficiency and enhanced hinterland connectivity, that could strengthen the competitiveness of Southern European ports relative to the Northern European port range. More recently, Ferrari and Tei (2020) analyse the potential effects of China's Belt and Road Initiative (BRI) on Mediterranean maritime transport, highlighting how new investment flows and shifting trade patterns may further reshape port hierarchies and network configurations in the region. Their findings suggest that, although the BRI may create new opportunities for Mediterranean ports, it may also intensify competitive pressures and reinforce asymmetries within the regional port system.

Alongside empirical studies, theoretical contributions have also provided important insights into the structural evolution of Mediterranean maritime networks. Foschi (2002) develops scale-free and dynamic models to explain the emergence and evolution of hub-and-spoke networks in the Mediterranean maritime system. Drawing on network theory, the study shows how port systems may evolve toward highly hierarchical configurations in which a small number of hub ports progressively attract a disproportionate share of connections and traffic. Foschi highlights the role of cumulative advantages and preferential attachment mechanisms in shaping maritime network structures, suggesting that early advantages in connectivity or geographic position can lead to persistent dominance over time. This theoretical framework offers a foundation for understanding the structural polarisation of Mediterranean maritime networks and anticipates later empirical findings on hub concentration and network dependency.

Finally, additional insights into the competitive positioning of Mediterranean ports are provided by two related working papers by Cazzaniga Francesetti and Foschi (2002, 2003). The first study focuses on the persistent tendency of Italian container flows to be routed through Northern European ports. It highlights the importance of logistics efficiency, hinterland accessibility, service reliability and network integration in shaping these routing decisions. Despite their geographical proximity to major trade routes, Mediterranean ports have historically faced structural and organisational weaknesses that limit their competitiveness. Building on this analysis, the second paper examines the specific implications of hub-and-spoke network configurations in the Mediterranean, emphasising how network topology, carrier strategies and port specialisation contribute to distinctive regional dynamics. Together, these studies shed light on the structural constraints and policy challenges affecting Mediterranean ports and underline the need for coordinated strategies aimed at strengthening their network positioning and reducing dependency on external hub regions.

Overall, the literature highlights how the development of hub ports in the Mediterranean has been shaped by a combination of geographical advantages, shipping network strategies and broader economic and institutional dynamics. The strategic location of several Mediterranean ports along the main east–west maritime corridor has favoured the emergence of transshipment hubs capable of attracting large volumes of container traffic through hub-and-spoke network configurations. At the same time, empirical studies show that these hubs operate in a highly competitive and volatile environment, as their traffic volumes depend heavily on the strategic decisions of global shipping lines and alliances. Moreover, both theoretical and empirical contributions suggest that Mediterranean maritime networks tend to evolve toward increasingly hierarchical and polarised structures, where a limited number of major hub ports concentrate a large share of connections and traffic.

### 3.2.3. Complex Network Analysis on maritime Hub'n'spoke structure

In recent years, increasing attention has been devoted to the application of network-based analytical approaches to the study of maritime transport systems. Among these approaches, Complex Network Analysis (CNA) has become an increasingly common framework for examining the structural characteristics of maritime transport networks and their organisation into hub-and-spoke configurations (Ducruet, 2020). This methodological perspective allows researchers to analyse the topology of shipping networks, identify central nodes within the system and evaluate the hierarchical organisation of global maritime flows.

One of the defining features of maritime networks is their non-planar nature, meaning that the crossing of network edges does not generate additional nodes; nodes exclusively represent ports rather than intersections of routes (Rodrigue, 2024). This characteristic distinguishes maritime networks from many terrestrial transport systems and reinforces the importance of ports as the fundamental nodes structuring global shipping connectivity.

Within this analytical framework, the structural properties of maritime networks have often been examined through the concepts of scale-free networks (Barabási and Albert, 1999) and small-world networks (Watts and Strogatz, 1998). A scale-free network is characterised by the presence of a small number of highly centralised nodes and a large number of nodes with low degree, following a power-law distribution and reflecting a highly hierarchical structure. By contrast, the small-world property describes networks characterised by strong local clustering and dense interactions within communities, representing tightly connected regional subsystems embedded within the global maritime network.

Building on these theoretical foundations, Ducruet and Notteboom (2012) demonstrate that the observed structure of the global maritime network depends strongly on the way the network itself is reconstructed. When the network is defined on the basis of direct port-to-port connections, a scale-free structure emerges that clearly illustrates the dominance of hub ports over secondary ports. Conversely, when indirect connections are taken into account, the network displays small-world characteristics, revealing strong regional integration within maritime systems. Despite these different representations, the authors show that highly central nodes tend to connect preferentially with other highly central nodes, as evidenced by assortativity and rich-club coefficients. This finding confirms the existence of a global hierarchical structure characterised by a limited number of dominant ports that are strongly interconnected and embedded within dense regional sub-networks. Similar conclusions are reached by Hu and Zhu (2009), who demonstrate that maritime shipping networks exhibit scale-free properties governed by power-law degree distributions, reinforcing the view of global shipping as a structurally hierarchical system.

Early empirical applications of network analysis to maritime transport also highlighted the progressive emergence of hub-and-spoke configurations. McCalla et al. (2005), for example, analyse what they define as network redundancy (or density) using the β value, calculated as the ratio between the number of connections and the number of ports in the network. Their analysis of the Caribbean basin reveals a decline in network density over time, associated with the increasing adoption of hub-and-spoke services in the region.

In parallel, several studies have used specific centrality measures derived from Complex Network Analysis to identify and characterise hub ports within maritime networks. Building on the conceptual framework proposed by Fleming and Hayuth (1994), who identified centrality and intermediacy as fundamental characteristics of transport hubs, Ducruet et al. (2010) and Ducruet and Notteboom (2012) employ measures such as degree centrality and betweenness centrality as operational proxies for these attributes. Additional metrics, including closeness centrality and eigenvector centrality, have also been applied to the analysis of hub port roles within shipping networks (Zhao et al., 2014). Closeness centrality captures the proximity of a node to all other nodes in the network, measured by the minimum number of connections required to reach them, while eigenvector centrality assigns importance to a node based on the centrality of the nodes to which it is connected.

While the hierarchical nature of maritime networks might theoretically increase their vulnerability, particularly in scale-free systems where disruptions affecting highly central nodes can have widespread effects, empirical research suggests that global shipping networks exhibit a significant degree of resilience. Wang et al. (2016) argue that the spatial configuration, high coastal density and polycentric structure of maritime networks contribute to their robustness. This resilience is further reinforced by the presence of nearby "pivot ports", which can act as alternative nodes in the event of disruptions affecting major hubs.

### 3.2.4. "Spoke centered" analysis on Hub'n'spoke networks

In addition to analysing the structural properties of maritime networks, recent research has increasingly focused on the uneven distribution of connectivity and vulnerability within hub-and-spoke systems, particularly with regard to the position of secondary or peripheral ports. Within this strand of literature, several studies have examined how dependence on major hubs shapes the integration of smaller ports into global maritime networks and influences their exposure to systemic risks.

Ducruet (2020) emphasises that most of the literature addressing the vulnerability of hub-and-spoke maritime networks through complex network analysis has primarily focused on hub ports rather than secondary ports. The author distinguishes two main analytical perspectives: "hub-centred" and "spoke-centred" approaches. The former focuses on network vulnerability resulting from hub failures, assessing the systemic consequences of disruptions affecting major nodes. By contrast, the latter aims to identify vulnerable nodes and analyse their dependence on specific hubs, often through case studies of particular regions. This approach sheds light on the differentiated exposure of secondary ports within maritime networks.

The analyses developed in this chapter belong to the second strand of literature, focusing on themes such as peripherality, the uneven distribution of trade flows within hub-and-spoke systems, and hub dependency. With regard to peripherality, Ball (1996) argues that it can be quantified through market accessibility models and effectively corresponds to an indicator of isolation. Peripheral areas are structurally disadvantaged due to their geographical remoteness, which translates into higher transport and production costs.

Although not explicitly framed in terms of peripherality, earlier contributions by Taaffe et al. (1963) and Hayuth (1985) indirectly address this issue illustrating how the cargo specialisation in maritime transport and the introduction of the container technology have led to the concentration of maritime flows in a limited number of ports. These ports progressively centralised port calls and direct international connections at the expense of smaller regional ports, benefiting from greater infrastructure investment and stronger hinterland penetration. Hayuth (1981) explicitly refers to this dynamic as the “peripheral port challenge”, noting that phases of traffic concentration are often followed by phases of deconcentration driven by diseconomies of scale in major load centres. During these phases, smaller peripheral ports compete with both large hubs and other regional ports in order to attract maritime traffic.

Subsequent research has further expanded these conceptual frameworks. Notteboom and Rodrigue (2005, 2010), for instance, extend earlier port development models by incorporating the emergence of hub-and-spoke port systems, highlighting how such systems can influence the levels of peripherality affecting both secondary ports and more developed gateway ports. Similarly, Slack and Wang (2002) analyse the challenges faced by peripheral ports, often feeder ports, within Asian port systems. Their study shows that the Asian maritime system historically exhibited a higher degree of hub dominance than those of Europe and North America, largely due to the central roles played by major hubs such as Singapore and Hong Kong.

Several studies have also examined how ports attempt to adapt strategically within hub-dominated systems. These contributions highlight the role of cost advantages, such as lower land and labour costs, in shaping competition among ports and influencing the decisions of shipping lines, terminal operators and institutional actors. Feng and Notteboom (2013), for example, analyse small and medium-sized ports in Northeast China and highlight their stronger orientation towards domestic and regional flows. Although these ports could potentially compete with major gateway ports that benefit from stronger inland connections, the authors emphasise the uncertainty created by the evolving strategies of the region’s dominant hub ports.

Within maritime network analysis, the concept of peripherality has also been examined by analysing regional port systems in relation to the global maritime network. Fraser et al. (2016) investigate changes in the degree of peripherality of South African ports between 1996 and 2011. Their analysis uses the Beta and Gamma indices to evaluate regional network characteristics and the Gini coefficient to measure the concentration of links and nodes. At the global scale, they assess variations in the betweenness centrality and eccentricity of regional ports. Similarly, Tovar et al. (2015) analyse the Canary Islands port system, contrasting the central role of the hub port of Las Palmas with the more peripheral position of the port of Tenerife within the Atlantic maritime network.

A related body of literature focuses on the uneven distribution of maritime traffic across hub-and-spoke systems. Wang et al. (2018), for example, argue that the Maritime Silk Road (MSR) initiative has transformed the Chinese maritime system, shifting it from a strongly hierarchical configuration towards a more networked structure in which secondary ports can achieve hub status and smaller ports become more specialised. In a complementary analysis, Mou et al. (2018) examine MSR ports using degree centrality and the Herfindahl-Hirschman Index (HHI) to measure traffic concentration. Their results reveal a highly imbalanced network in which a small number of major hubs, particularly in China and Singapore, control the majority of interregional flows, approaching quasi-monopolistic conditions. In contrast, small and medium-sized ports tend to remain largely inward-oriented, with traffic concentrated within regional markets and limited direct access to global shipping routes.

Further studies analysing the MSR maritime network confirm the persistence of hierarchical network structures. Jiang et al. (2019) demonstrate that the network exhibits scale-free properties, suggesting that major hub ports benefit from productive investments located in close proximity in order to optimise logistics costs and cargo movements. Similarly, Guo et al. (2017), analysing the maritime network connecting China, South Korea and Japan, identify a highly hierarchical, scale-free, multi-hub system that is robust overall but characterised by differentiated vulnerability across hub nodes and regions. Smaller ports within this system remain largely confined to local and feeder traffic. Lu et al. (2018), focusing on the Bohai Rim port network, further enrich this perspective by introducing the concepts of hub and authority centrality in order to capture connectivity with high-impact ports within the system.

Beyond these structural analyses, another important research strand has explicitly operationalised the concept of hub dependency, focusing on the condition of relative weakness and dependence characterising the connections of spoke ports. One pioneering contribution is Ducruet (2008), who analyses the evolution of North Korea's maritime network and identifies an increasing dependence on foreign hub ports, primarily located in South Korea, for international maritime connectivity. Using the Gini coefficient, the author examines variations in traffic concentration within the first maritime ring, consisting of directly connected ports, and analyses indirect connectivity towards the outer maritime ring, composed of ports reached through indirect connections. The study shows that rising hub dependency is associated with increasing regionalisation of maritime networks.

Building on this approach, Ducruet et al. (2010) analyse ports in Northeast Asia by comparing degree centrality with hub dependency. Their results reveal an inverse relationship between the number of connections and the concentration of traffic on those connections, demonstrating that hub dependency can be interpreted as a form of relative network vulnerability. In the case of Chinese ports, the authors show that emerging peripheral ports cannot become dominant without initially relying on existing hubs or large gateway ports. In order to evolve towards a more balanced distribution of traffic, such ports must improve not only traffic volumes but also their long-term strategic position within the network. Interestingly, the study finds no direct correlation between a port's network centrality and its throughput levels: ports with high traffic volumes may still perform primarily gateway functions and remain dependent on hub ports, while ports with more central positions within the network may handle relatively lower volumes.

Finally, Mohamed-Chérif and Ducruet (2016) analyse hub dependency dynamics in the Maghreb port system. Their findings indicate that hub dependency increased during the 2000s, particularly in Tunisia and Algeria. During this period, Marsaxlokk and Cagliari functioned as key hubs connecting east–west trunk routes. However, by 2011 a shift towards the Moroccan port of Tanger Med could be observed, reflecting stronger regional integration. Despite increasing maritime connections with Marsaxlokk, Morocco itself appears significantly less dependent on external hubs. The study also highlights infrastructural constraints, such as berth length, water depth and equipment capacity, in Tunisian and Algerian ports as key factors explaining their continued dependence on hub ports.

Further research explicitly links hub dependency to issues of network vulnerability. Xu and Xia (2017), for example, analyse China's overseas maritime connections and show that increasing reliance on a limited number of foreign hub ports improves long-distance connectivity but simultaneously increases vulnerability to disruptions affecting those hubs. Similarly, Zreik et al. (2017), examining the collapse of the Soviet maritime shipping network through cluster analysis, demonstrates how the disintegration of highly centralised and hub-dependent network structures can lead to rapid fragmentation and loss of connectivity.

Overall, this body of literature highlights that hub-and-spoke maritime systems generate asymmetric patterns of connectivity, in which a limited number of hub ports concentrate strategic functions while secondary ports remain structurally dependent on them for access to global shipping networks. Although this configuration can enhance efficiency and connectivity at the global scale, it may also increase vulnerability for peripheral ports and create uneven exposure to disruptions within maritime transport systems. Consequently, analysing hub dependency and peripherality provides important insights into the structural inequalities embedded within global maritime networks and into the strategic challenges faced by secondary ports seeking to strengthen their position within these systems.

### 3.2.5. Network analysis and Vulnerability of hub'n'spoke

Based on the literature, the assessment of network disruption in maritime studies employs targeted methodologies to evaluate both the vulnerability and resilience of shipping networks. Scholars such as Viljoen and Joubert (2016) and Lhomme (2015) model targeted disruptions, simulating the failure of specific critical links or nodes, to measure the subsequent degradation in global or regional connectivity. These attacks are often informed by centrality metrics, particularly betweenness and degree centrality, which help identify hubs and corridors whose removal would maximally fragment the network. For instance, Lhomme (2015) contrasts these topological measures with throughput-based indicators to highlight that the most central nodes in terms of connectivity are not always the most critical for cargo flows, underscoring the need for multi-criteria vulnerability analysis.

Similarly, research on hub dependency, such as Xu and Xia's (2017) examination of China's overseas connections, reveals how over-reliance on a few major hubs can amplify systemic risk. Disruption studies also extend to critical maritime corridors; Wu et al. (2019), for example, analyze how the blockade of a strategic waterway, like a major strait, can cascade through the global liner network, severely reducing efficiency and rerouting complexity. Importantly, the resilience of maritime networks is not merely passive but involves active adaptation.

Post-disruption analyses, including studies of traffic redistribution (Xu et al., 2024), demonstrate that networks can absorb shocks through the rerouting of vessels to alternative ports and routes, thereby maintaining overall functionality. This capacity for reorganization is further evidenced in longitudinal studies of disaster recovery: Rousset and Ducruet (2020), comparing events such as the Hanshin Earthquake and Hurricane Katrina, observe that network density often increases after a major disruption, suggesting a phase of intensified connectivity and cooperation among surviving ports as the system stabilizes and rebuilds.

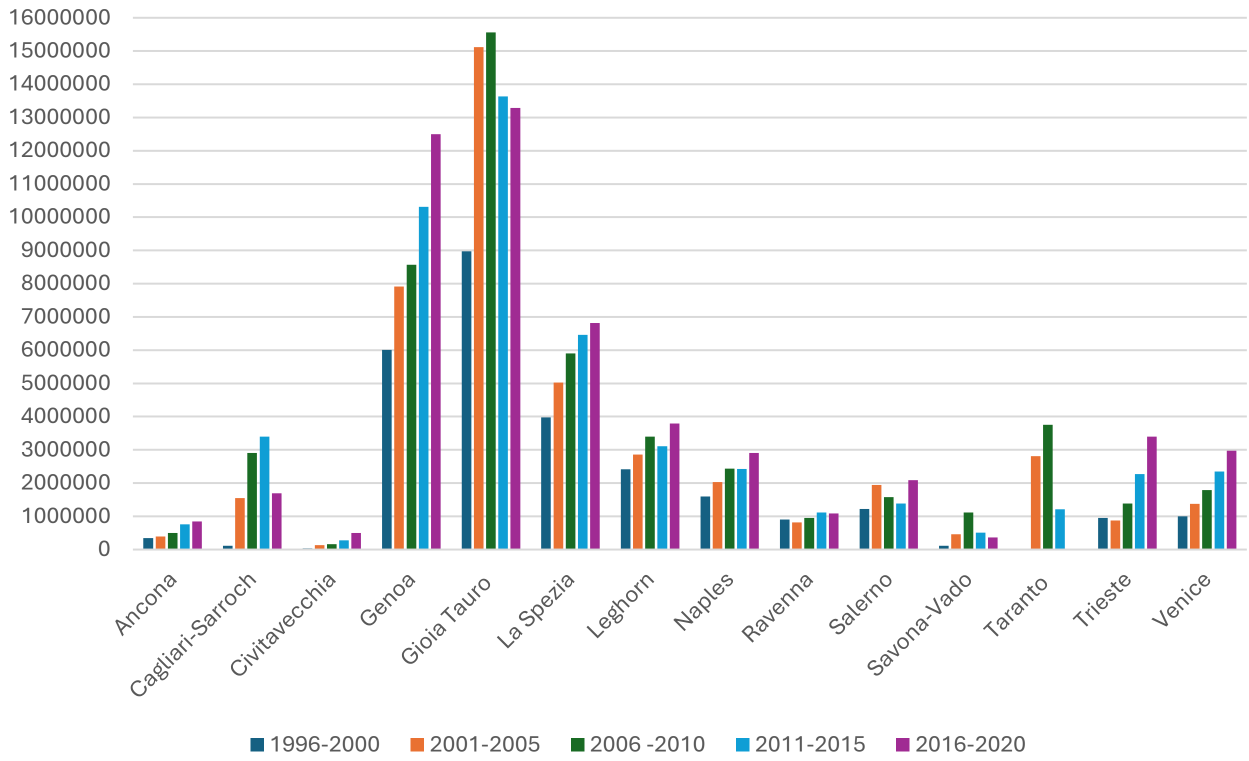
Thus, the methodologies for studying disruption encompass both static, targeted attack simulations and dynamic analyses of post-shock reconfiguration, collectively painting a picture of maritime networks as complex systems whose vulnerability is defined by their critical nodes and links, yet whose resilience lies in their inherent redundancy and adaptive capacity.

## 3.3 Metodology and Data

### 3.3.1. Maritime dataset

The analyses in this chapter consider 14 Italian ports that have handled a significant volume of container transport in recent decades. Using ASSOPORTI data on port movements, which records the movement of goods in Italian ports, it has been possible to reconstruct container traffic in these ports between 1996 and 2023. To take into account the varying levels of container traffic that ports have experienced over time, TEUs have been aggregated over five-year intervals as can be seen in Figure 21. Therefore, ports that had container traffic exceeding 200,000 TEUs in at least one of the five-year intervals were taken into consideration.

*Figure 21 Five-year TEUs handled by the ports under study*




*Source: Personal elaboration of ASSOPORTI data.*

To analyse the movement of ships that called at ports, data from Lloyd's List was used. The data from Lloyd's List provides the date and time of entry into a port, the ship's identification code, and the ship's size in DWT. Using this information, it is possible to trace every voyage from the port of departure to the port of arrival. It covers approximately 80% of the world's merchant fleet and 70% of the world's trade volumes Ducruet (2008).

### 3.3.2. Metodology

The network of maritime connections of the Italian ports under analysis was reconstructed using Lloyd List port entry and exit data to determine individual ship voyages between each pair of ports. This data also provides a Vessel ID for each ship, along with its respective Deadweight Tonnes (DWT), which can be used to calculate the cargo capacity distribution on each connection. The way in which a maritime network is reconstructed significantly influences the centrality measures and properties of the network.

As previously mentioned, maritime networks are non-planar and, according to the literature, they have mainly been reconstructed according to two macro-structures: Space-L and Space-P. In the former (Space-L), the edges represent the connections between ports (nodes) that were actually made by the ship. For example, if a ship travels from Port 1 to Port 2, then to Port 3 and finally to Port 4, Port 1 and Port 4 are connected via a topological path of three edges in the network.

This structure realistically reflects ship movements and direct connections between ports, as well as the routes that ships take. It can also be better adapted to "Trump-type" maritime trade, where goods are loaded at one port and unloaded entirely at the port of arrival. This business model is more characteristic of bulk transport. However, containerized maritime transport is organized according to a commercial model based on liner services, whereby a vessel operates along more or less circular routes, calling at a predefined set of ports. Containers loaded at a given port may be destined to any of the ports served along the route. To adequately represent this type of relationship, characterized by the mutual connectivity of all ports within a given service, the concept of the Space-P network has been introduced.

Within this network representation, a direct connection (edge) is established between every ports visited by the vessel over the course of the year. The commercial relevance of a port in terms of intermodal logistics is therefore not determined by the presence of direct connections with other ports, but rather by the set of ports interconnected with the port through the liner services.

The global maritime network was first reconstructed at both the Space-L and Space-P levels in the analyses carried out in this chapter. In light of this, centrality measures for Mediterranean ports were calculated, with those for Italian ports being examined in detail.

Subsequently, to analyse the vulnerability of the Italian port system and its constituent networks, an ego-network was reconstructed based on the Space-P network. In the literature, the analysis of the connectivity of a group of ports at country level has often been carried out using an 'Ego-network'.

For a given node, the ego network corresponds to a sub-graph where only its adjacent neighbors and their mutual links are included (Rodrigue, 2024). This was done at both the national level, where only the gateway ports were retained, and at the level of individual ports. The ego-networks were calculated by including all nodes within two edges of those representing Italian ports, to encompass all ports reachable via a single transhipment.

### 3.3.3. Network properties

Graph density (GD) is the ratio between the number of connections m in the network compared to the maximum possible connection *n(n-1)*, *n* is the number of node (Bedoya-Maya et al, 2025). This measure underlines a growing rationalization of the network. In a highly hierarchical network, such as hub-and-spoke networks, density values decrease as they increase with highly connected graphs. The density value of a fully connected network is 1. The density of the network is a value that tends to increase after punctual crisis on maritime networks (Rousset and Ducruet,2020). It is preferred to the similar Gamma Index (Rodrigue,2024) because it better represents non-planar networks such as maritime networks. In an undirected graph the mathematical calculation of *GD* is:

*Eq. 4*

$$GD = \frac{m}{n(n-1)}$$

The Clustering Coefficient measures the extent to which a network tends to be organised in a (quasi)-cluster, i.e. a network where "my friends' friends are also my friends" (Faure et al. 2025). Consider a graph G(V,E), where $V$ is the set of vertices (here, ports) and $E$ is the set of edges (connections between ports). Let $\lambda i$ denote the number of triangles (three nodes where each node is connected to the other two) involving node $i$, and let $\tau_i$ denote the number of triplets (three nodes connected by two edges) centered at node $i$. The clustering coefficient at the node level can then be written as follows:

*Eq. 5*

$$C_{i=}\begin{cases}\frac{\lambda_i}{\tau_i} & if \ \ d_i \geq 2 \\ 0 & otherwise\end{cases}$$

And at the network level *Average Clustering Coefficient*: (in R è

*Eq. 6*

$$C(G) = \frac{1}{|V'|}\sum_{i \in V'} C_i$$

$V'$ è il subset di vertici in cui $C_i$è maggiore di 0, $V' = \{i \in V : d_i \geq 2\}$.

The *Global Clustering Coefficient*, also referred to as transitivity, measures the likelihood that adjacent nodes in a network are directly interconnected (Rodrigue, 2024). It is calculated as the ratio of the observed number of triangles in the graph to the maximum possible number of triangles. In complex networks, especially that's with high small-world characteristics, it can be found high transitivity alongside a low diameter (Watts and Strogatz, 1998).

*Eq. 7*

$$Gcc = \frac{3\lambda(G)}{\tau(G)}$$

$V'$ è il subset di vertici in cui $C_i$è maggiore di 0, $V' = \{i \in V : d_i \geq 2\}$.

## 3.3.4. Centrality measures

Degree centrality (Diestel,2017) is the simplest and most intuitive measure of a node's importance in a network. It is defined as the number of direct connections (edges) a node has. In a directed graph, this can be calculated as the in-degree or out-degree, respectively the sum of the incoming or outgoing connections of a node. In an undirected network, however, degree centrality is the sum of all connections of the node to other nodes. An undirected graph is defined as a pair $G = (V, E)$, where $V$is the set of nodes (or vertices) and $E$is the set of unordered pairs of nodes (i.e., $\{v, u\}$). For a node $v \in V$, the degree $k(v)$(or $\deg(v)$) is the number of edges incident to $v$. In terms of the adjacency matrix $A = (a_{ij})$, which is a matrix built from the connections between nodes,

*Eq. 8*

$$k_i = \sum_j a_{ij} \, ,$$

where $a_{ij} = 1$ if there is an edge between nodes $i$and $j$, and $a_{ij} = 0$ otherwise.

A directed graph (or digraph) is defined as a pair $G = (V, A)$, where $V$is the set of nodes (or vertices) and $A \subseteq V \times V$is the set of ordered pairs of nodes, called directed edges (or arcs). For a node $v \in V$, two types of degree are defined.

The in-degree of $v$, denoted $k^{\text{in}}(v)$or $deg^{-}(v)$, is the number of edges entering $v$:

*Eq. 9*

$$k^{in}(v) = | \{(u, v) \in A\} |.$$

The out-degree of $v$, denoted $k^{\text{out}}(v)$or $deg^{+}(v)$, is the number of edges leaving $v$:

*Eq. 10*

$$k^{out}(v) = | \{(v, w) \in A\} |.$$

In terms of the adjacency matrix $A = (a_{ij})$, where $a_{ij} = 1$if there is a directed edge from node $i$to node $j$, and 0 otherwise:

*Eq. 11*

$$k_i^{out} = \sum_j a_{ij}\,, k_i^{in} = \sum_j a_{ji}\,.$$

Closeness centrality (Freeman, 1978) measures the topological distance of a node to all other nodes in the network. In this context, a node is considered more central the shorter its average distance to the other nodes is. Closeness centrality of a node u is the reciprocal of the average shortest path distance to u over all n-1 reachable nodes.

*Eq. 12*

$$Cc(u) = \frac{n-1}{\sum_{v=1}^{n-1} d(v,u)}$$

where d(v, u) is the shortest-path distance between v and u, and n-1 is the number of nodes reachable from u.

Betweenness centrality is a measure that more closely aligns with the concept of intermediacy, as suggested by Fleming and Hayuth (1994) as a characteristic of hubs. The value of this centrality is higher the more a node lies on the topological (shortest) paths between every pair of nodes in the network. We can think of the node with the highest betweenness centrality as the most effective intermediary within the network. Betweenness centrality (Brandes,2008) of a node is the sum of the fraction of all-pairs shortest paths that pass through the node $v$.

*Eq. 13*

$$c_B(v) = \sum_{s,t \in V} \frac{\sigma(s,t|v)}{\sigma(s,t)}$$

Where $V$ is the set of nodes, $\sigma(s,t)$ is the number of shortest $(s,t)$ -paths, and $\sigma(s,t|v)$ is the number of those paths passing through some node $v$ other than $s$ and $t$.

Eigenvector centrality is a measure of node importance in a network, assigning higher scores to nodes that are connected to other highly central nodes. Unlike degree centrality, which only considers the quantity of connections, eigenvector centrality considers the quality or influence of a node's neighbours. Formally, a node's centrality is proportional to the sum of the centralities of the nodes to which it is connected. This makes eigenvector centrality particularly useful for identifying structurally influential actors within a network. A node therefore attains a high eigenvector centrality when it is linked to other highly influential nodes, reflecting its embeddedness within the core of the network.

## 3.4 Analysis of results

### 3.4.1. Centality measures

The analysis of centrality measures was conducted by examining the reconstructed maritime network both under a Space-L structure and a Space-P structure. This section first presents an analysis at the scale of the Mediterranean basin, before focusing specifically on the Italian ports included in the study.

Figure 22 illustrates the evolution between 2000 and 2023 of degree centrality and betweenness centrality for ports in the Mediterranean basin, calculated on the global maritime network using a Space-P structure. These two indicators can be interpreted as descriptive measures of the centrality and intermediacy characteristics typically associated with transport hubs (Fleming and Hayuth, 1994; Ducruet and Notteboom, 2012). As shown in the maps, the ports with the highest betweenness centrality correspond to those that have assumed the role of transshipment hubs at the Mediterranean scale.

Over the time span represented in the maps, the ports highlighted with darker blue shades, corresponding to the three highest classes, include Port of Algeciras, Port of Tangier Med, Port of Valencia, Port of Barcelona, Port of Gioia Tauro, Port of Marsaxlokk, Port of Piraeus, and Port of Ambarli.

In 2000, the ports of Algeciras and Piraeus display the highest betweenness centrality, followed by Valencia, Barcelona, Gioia Tauro, and Marsaxlokk, which belong to a slightly lower betweenness class. Valencia emerges as the port with the highest degree centrality in the entire Mediterranean.

By 2005, Algeciras further increases its betweenness, entering the fifth class, while the number of ports in the fourth class decreases to three: Valencia, Barcelona, and Gioia Tauro. During this period, stronger competitive dynamics begin to emerge, as evidenced by the increasing betweenness of Ambarli and the decreasing betweenness of Piraeus. Additionally, the port of Marsaxlokk shows a reduction in both degree and betweenness, while degree centrality simultaneously increases in the ports of Port of Cagliari and Port of Taranto. Both ports began to perform transshipment hub functions during these years (Ivona, 2010; Notteboom, 2010; Notteboom et al., 2014).

In 2010, a marked increase in both betweenness and degree centrality can be observed for the ports of Valencia and Marsaxlokk. The rise in betweenness of these two ports correspond to a decline in nearby hub ports. In the case of Valencia, both Algeciras and Barcelona experience a reduction in betweenness (with Barcelona also showing a decline in degree). In the case of Marsaxlokk, the decline mainly affects Gioia Tauro and Piraeus.

By 2015, a clear decrease in centrality can be observed for Valencia and Marsaxlokk. Conversely, the ports of Gioia Tauro and Piraeus show increases in both betweenness and degree, while Taranto disappears from the hub landscape. Near the Strait of Gibraltar, the role of Tangier Med begins to consolidate, recording a rise in betweenness and partially compensating for the decline in degree observed in Valencia.

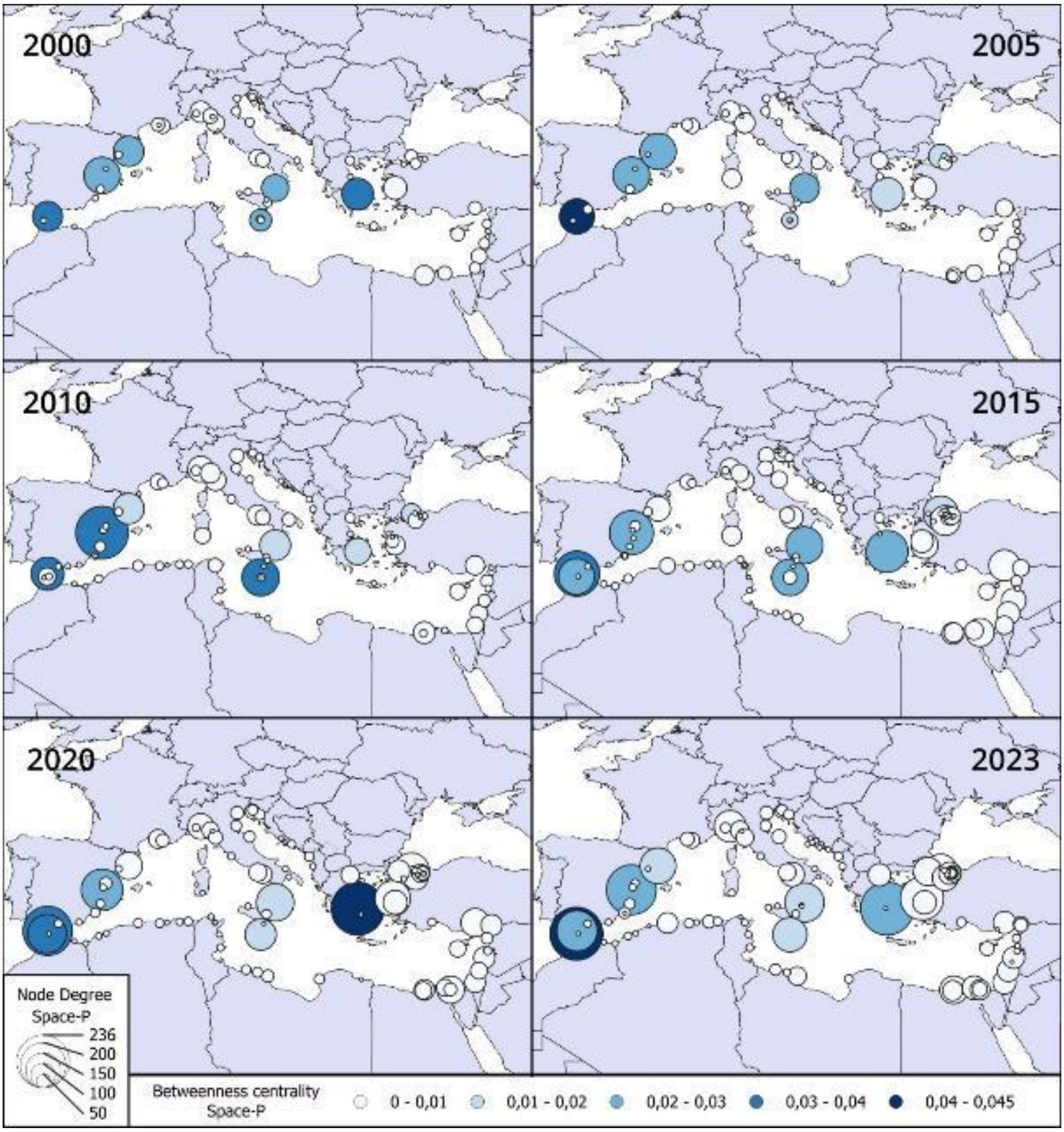
In 2020, a strong increase in both betweenness and degree is recorded for Piraeus, while betweenness declines in the central Mediterranean hub ports, namely Gioia Tauro and Marsaxlokk. Tangier Med continues to grow in betweenness, reaching levels comparable to Algeciras.

The situation in 2023 reveals a new hierarchical configuration. Tangier Med occupies the class with the highest betweenness centrality, followed by Valencia, which increases its degree centrality, and Piraeus, which maintains a high degree value but records a decline in betweenness. Algeciras is overtaken by Tangier Med in both degree and betweenness, although it still remains above the threshold value of 0.02. The ports of the central Mediterranean show a slight increase in degree but remain characterized by lower betweenness values.

The longitudinal observation of these measures confirms the existence of strong competitive dynamics among geographically proximate hub ports, which appear to influence the evolution of their connectivity levels over time. The cases of Cagliari and Taranto illustrate how transshipment hub projects can rapidly increase the centrality of previously marginal ports, but can also lead to equally rapid declines, returning these ports to conditions of marginality.

Moreover, a significant volatility in the hierarchical role of these ports can be observed, consistent with patterns already identified in studies of container trade flows by several authors (Notteboom, 2010; Notteboom et al., 2019; Notteboom et al., 2023).

*Figure 22 Degree and betweennees centrality of ports (Space-P network) in the Mediterranean basin*




If we instead consider the ports belonging to the lowest betweenness class, namely those with values between 0 and 0.01, several geographical patterns related to their degree centrality can be observed.

Ports in North Africa, for example, generally maintain extremely low degree values, with the exception of Port of Algiers and Port of Misurata, which by 2023 appear to emerge as the main nodes within the region.

A similarly low level of degree centrality is also a common feature among smaller Spanish ports located in proximity to major hub ports.

By contrast, ports along the Eastern Mediterranean coast tend to display relatively high degree values but low betweenness centrality. A similar pattern increasingly characterizes ports along the Turkish coast, with the notable exception of Port of Ambarli.

### 3.4.2. Italian ports

Figure 23 and Figure 24 illustrates the evolution of the centrality degree of the Italian ports in Space-L and Space-P. Since 2000, the Port of Gioia Tauro, Italy's primary transshipment port, has consistently displayed a significantly higher level of centrality than other Italian ports in both Space-P and Space-L representations of the maritime network.

Looking specifically at other transshipment ports, Port of Cagliari and Port of Taranto show a rapid increase in degree centrality, followed by a sharp decline between 2005 and 2010, and until 2015 in the case of Cagliari.

Considering both network structures, ports located along the Tyrrhenian Sea tend to exhibit higher degree centrality values than other Italian ports, with the exception of Port of Civitavecchia.

However, when examining ports along the Adriatic coast, a common growth trend can be observed for Port of Ravenna, Port of Trieste, Port of Venice, and Port of Ancona, particularly in the Space-P network, with a marked increase for Venice beginning around 2010.Meanwhile, Genoa remains the most central Italian gateway port, while in southern Italy Salerno has experienced a substantial increase in centrality in recent years.

*Figure 23 Node Degree Space-L*

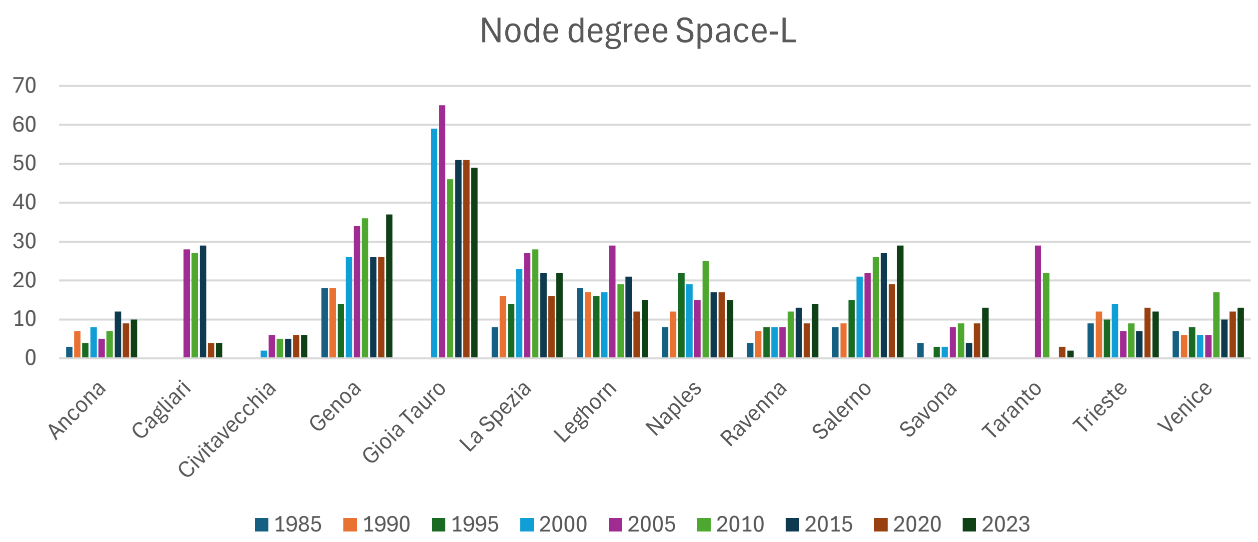
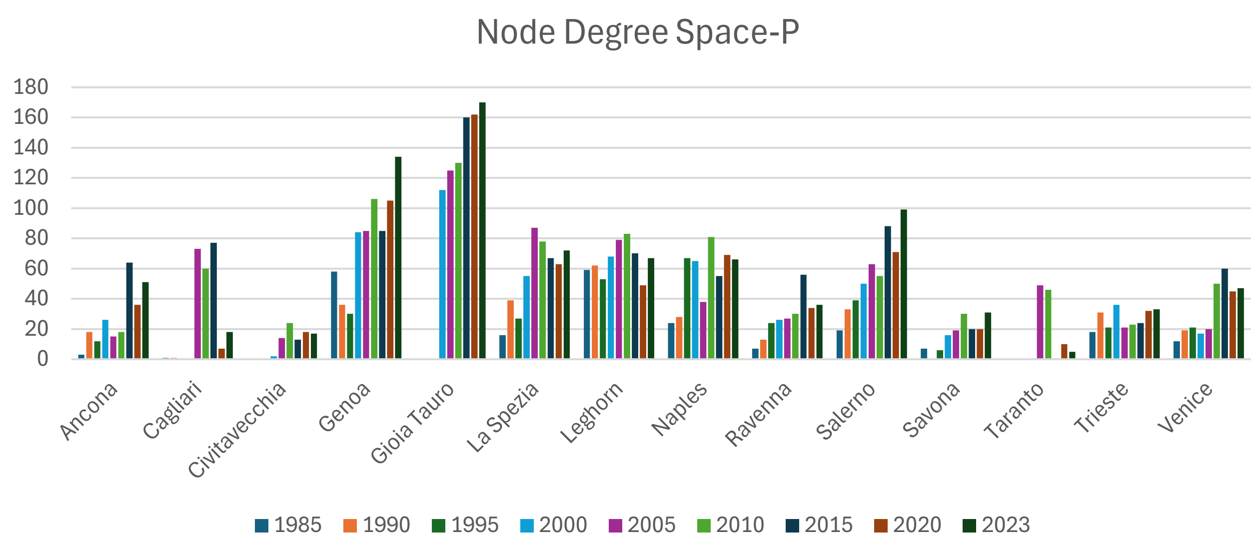


*Figure 24 Node Degree Space-P*




If we observe the betweenness centrality in Figure 25 and Figure 26, it can be seen a general trend towards the marginalisation of Italian ports within the maritime network. As also illustrated in both Figures, the Port of Gioia Tauro remains the Italian port with the highest betweenness centrality, although it also shows a decline by 2023.

Among gateway ports, Genoa and La Spezia exhibit the highest betweenness values. However, both ports appear to have experienced a decline since around 2015, although Genoa seems to have partially recovered in recent years.

For Cagliari and Taranto, an increase in betweenness can be observed during the years in which they operated as transshipment hubs. Nevertheless, their betweenness values remain relatively low given their hub status, confirming the difficulties they faced in integrating themselves into the global maritime network as major hub ports.

*Figure 25 Betweenness Centrality Space-L*

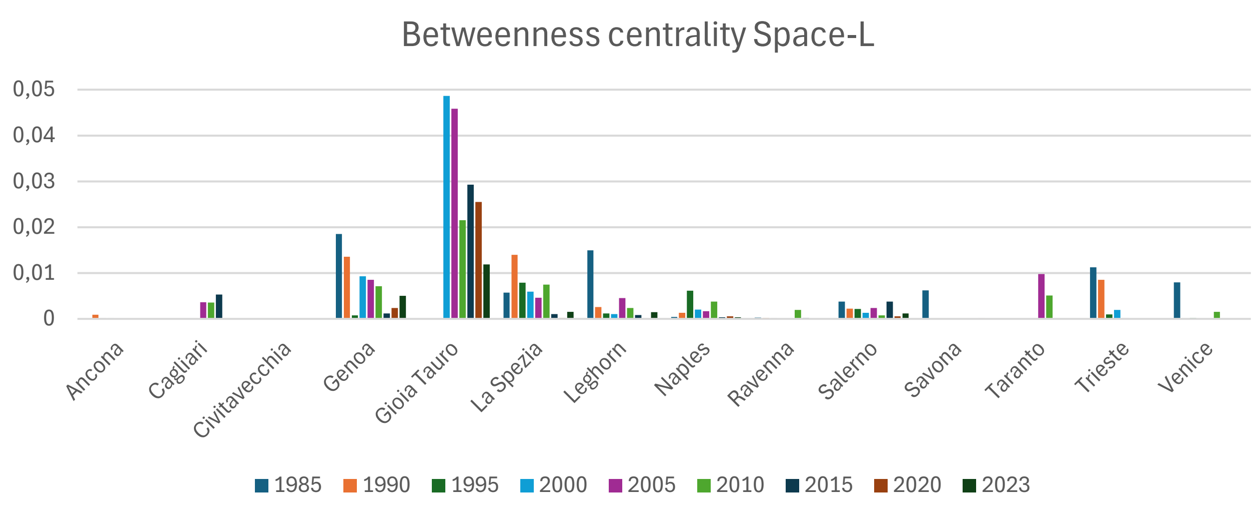
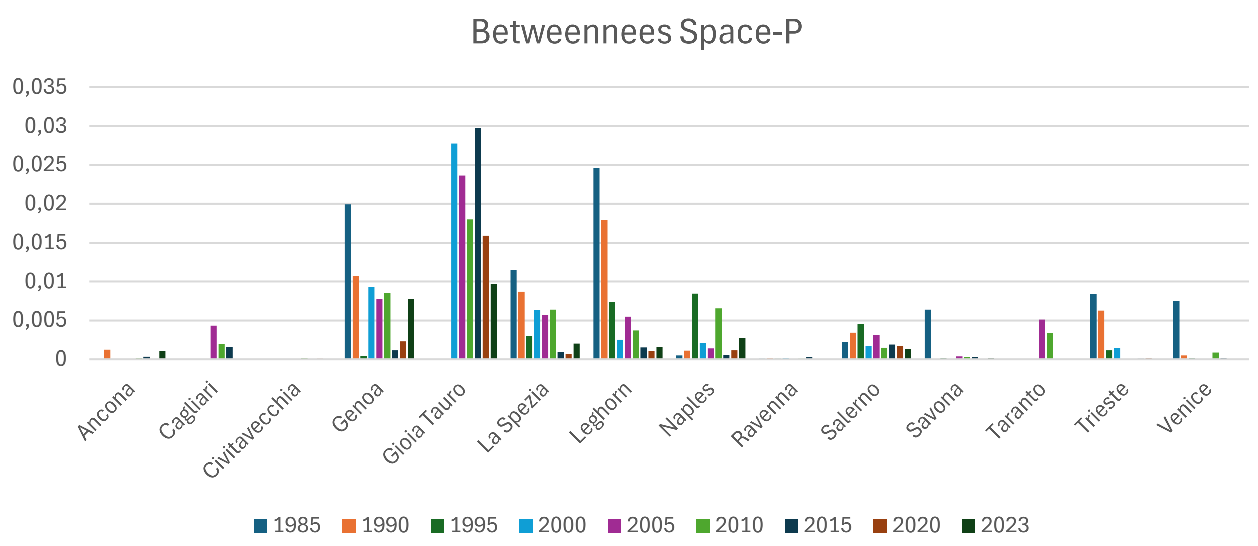


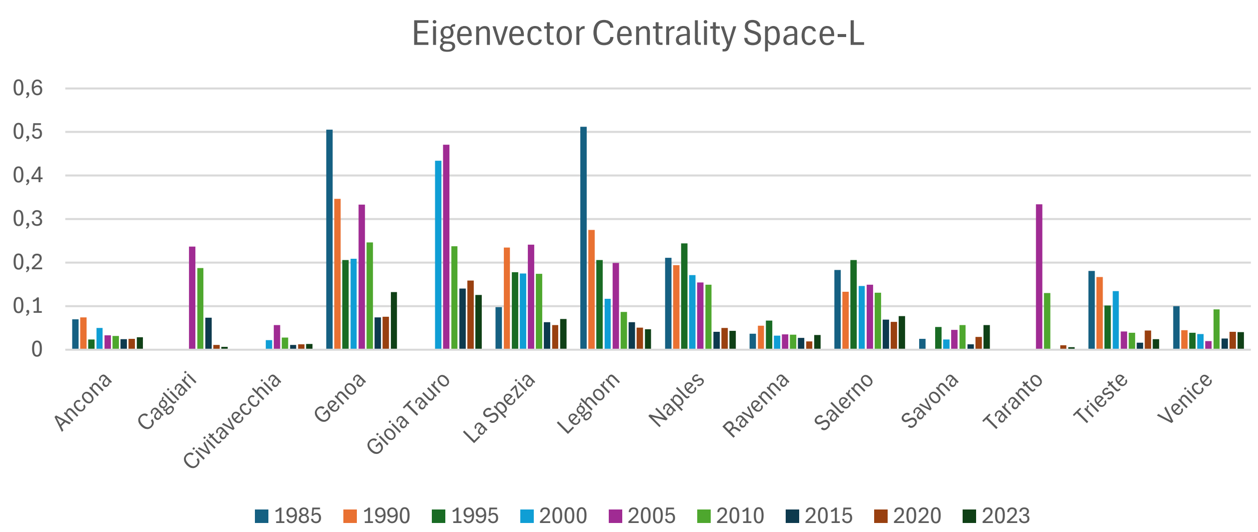
*Figure 26 Betweenness Centrality Space-P*




This process of peripheralization can also be observed through Figure 27 and Figure 28. Eigenvector centrality, shows a decline for several Italian ports, including Genoa, La Spezia, and Livorno, with the decrease becoming particularly pronounced after 2015.

Lower eigenvector centrality values can also be observed for Adriatic ports, with the Port of Trieste showing a sharp decline from 2005 onwards, indicating a rapid reduction in its connections with the most influential or highly connected ports in the network.

*Figure 27 Eigenvector Centrality Space-L*




Finally, this peripheralization trend is also clearly reflected in Closeness centrality, which shows a common and consistent decline across all Italian ports as shown in Figure 29 and Figure 30.

*Figure 28 Eigenvector Centrality Space-P*

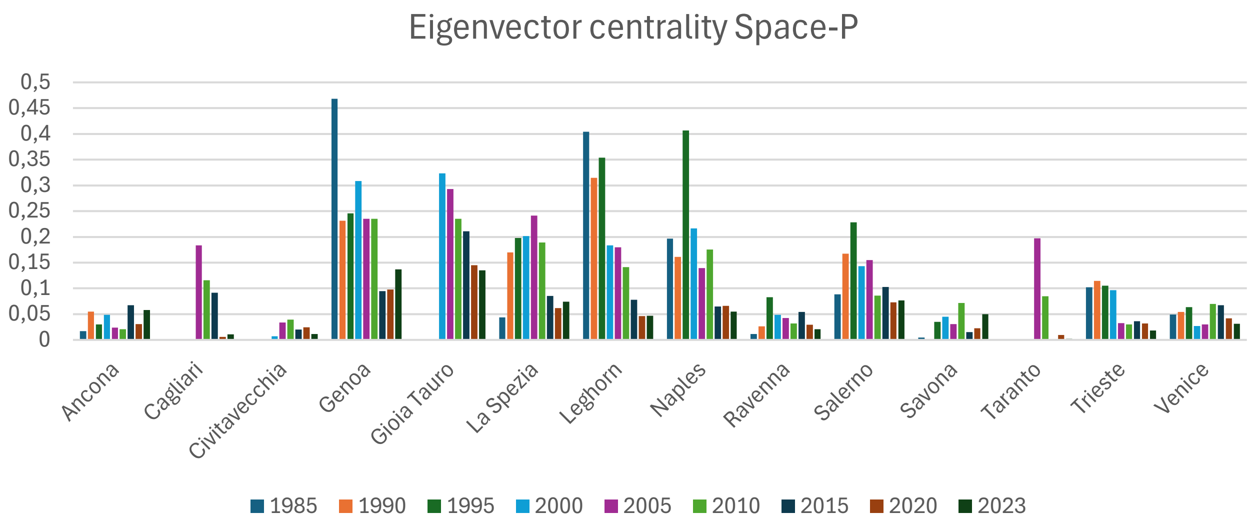



*Figure 29 Closeness centrality Space-L*

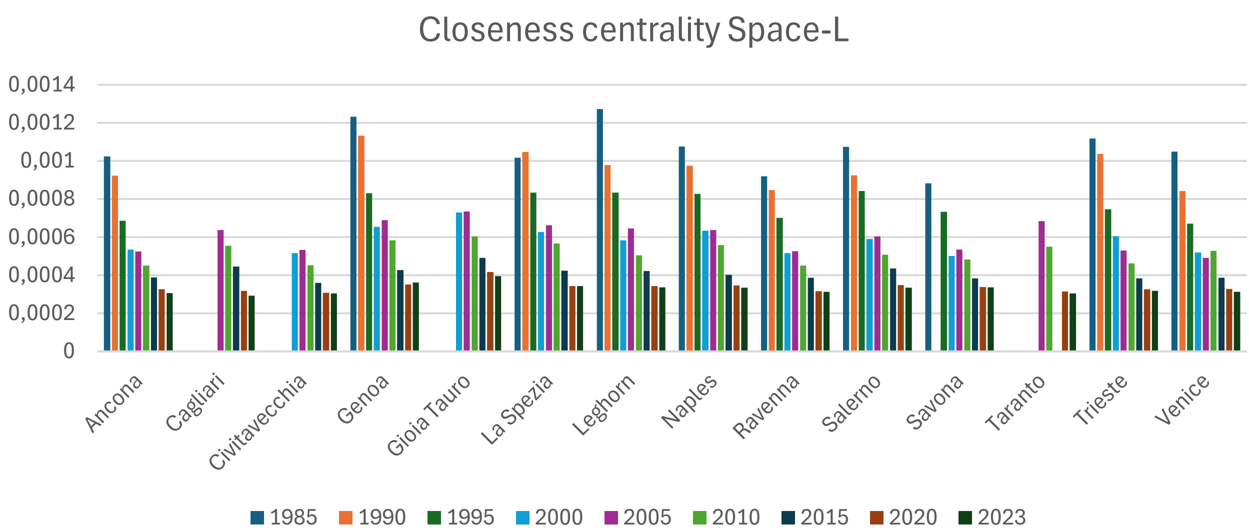
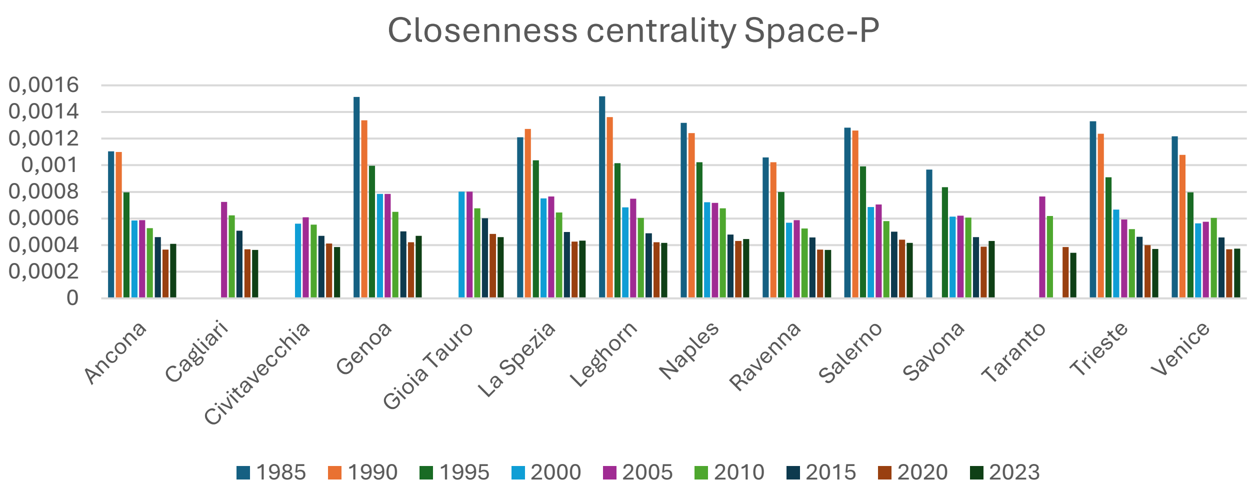


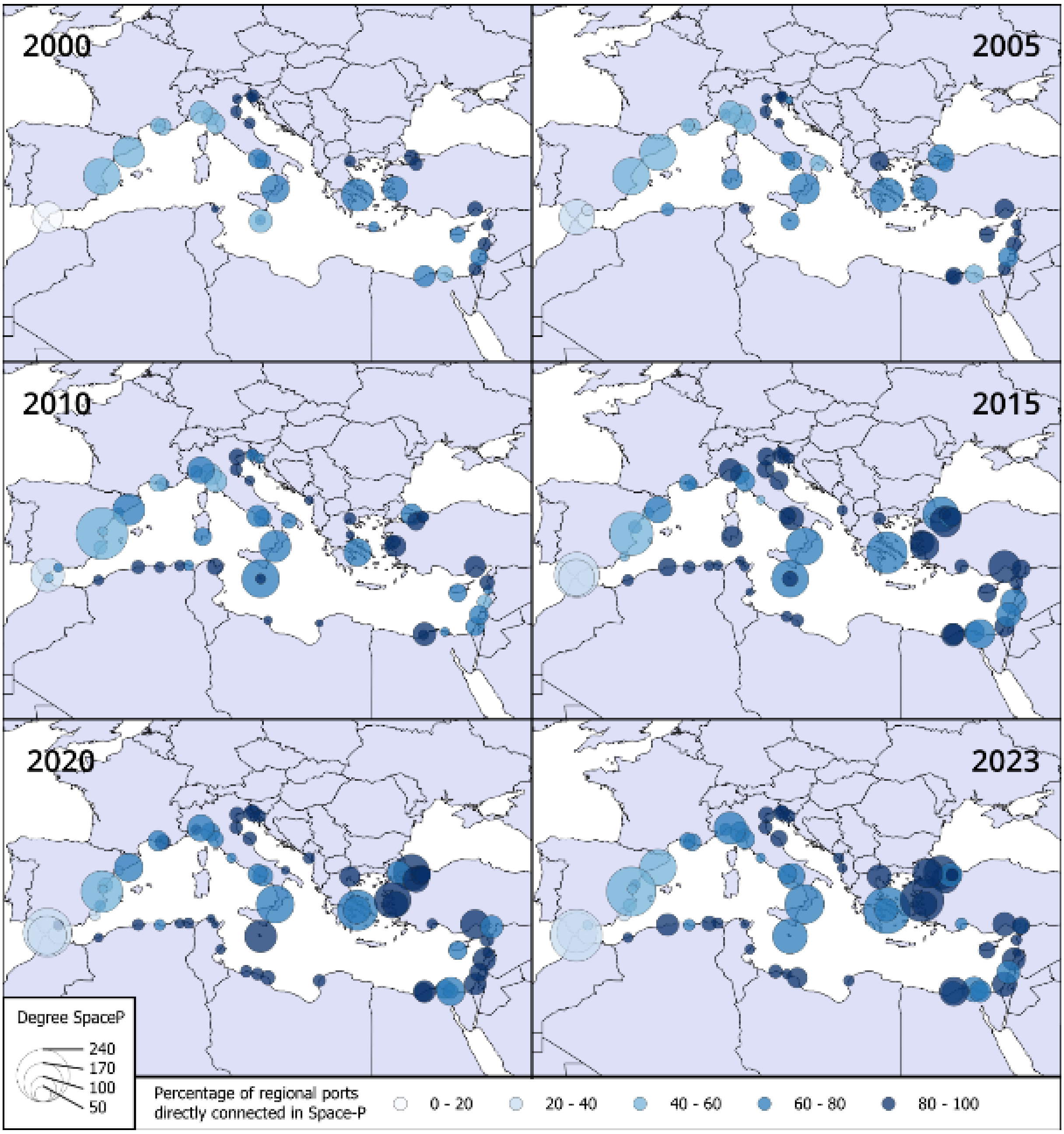

*Figure 30 Closeness centrality Space-P*



### 3.4.3. Regionalization

In this section, we examine the level of regionalization of maritime networks among Mediterranean ports. To provide an indicator of the regionalization of maritime traffic, all ports in the network generated from global container vessel movements were classified according to their geographical location. Based on this classification, all ports located along the Mediterranean Sea and the Black Sea were considered regional ports. Considering all Mediterranean ports, we then analyzed the direct connections reconstructed in the Space-P network, calculating the percentage of "regional" ports connected to each port relative to the total number of connected ports during a given year. The results are presented in Figure 31.

*Figure 31 Map of regionalization of mediterranean ports and their degree*




The maps show a general tendency toward the regionalization of direct maritime connections, particularly evident from 2010 onwards, across much of the Mediterranean. As can be observed in the 2000 and 2005 maps, ports in the western Mediterranean and in the port range extending from Valencia to Livorno display lower levels of regionalization in their port connections compared to the rest of the Mediterranean.

Ports in the central Mediterranean instead show higher levels of regionalization, while the areas with the most strongly regional traffic are located in the northern Adriatic and across much of the Eastern Mediterranean, with the exception of ports located near the Suez Canal.
From 2010 onwards, this trend becomes more pronounced. Ports such as Barcelona and Genoa increase the share of their regional connections, while several North African ports emerge with strongly regionalized traffic patterns.
By 2015, this phenomenon intensifies further, with Genoa, Cagliari, Naples, and Salerno entering the highest class of regional connectivity (dark blue).
From 2020 onwards, the trend partially reverses for some ports, such as Genoa and Barcelona, while Marsaxlokk increases its share of regional connections.
Nevertheless, a clear geographical pattern emerges, confirmed again in 2023, with highly regionalized traffic characterizing geographical areas such as North Africa, the Adriatic Sea, the Eastern Mediterranean, and the Turkish coast. Ports in these regions, despite often exhibiting high node degree, tend to maintain strongly regional traffic structures.

*Figure 32 Clustering coefficient Space-L*

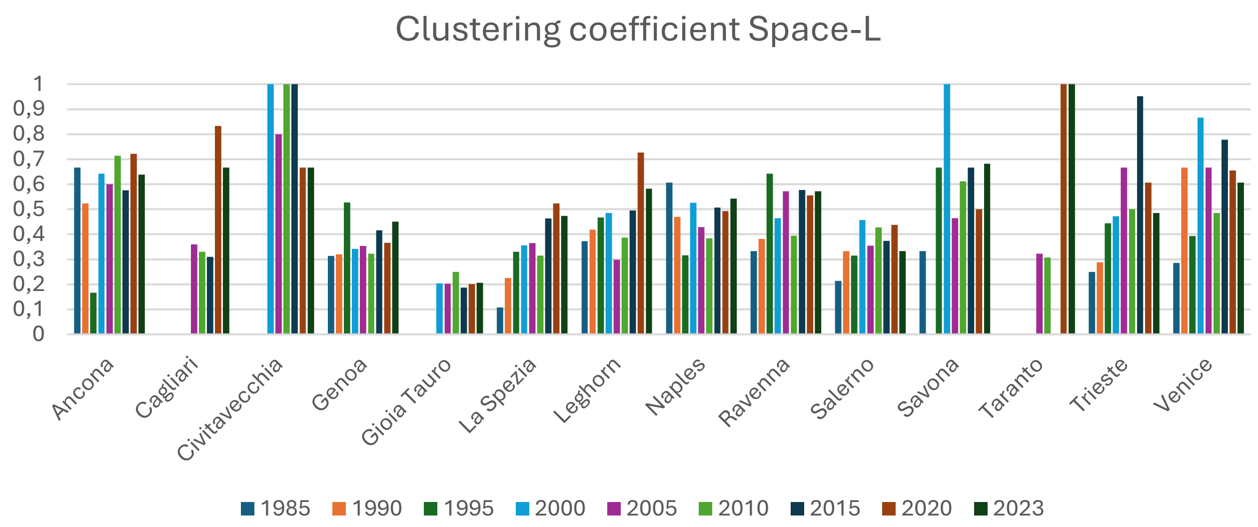
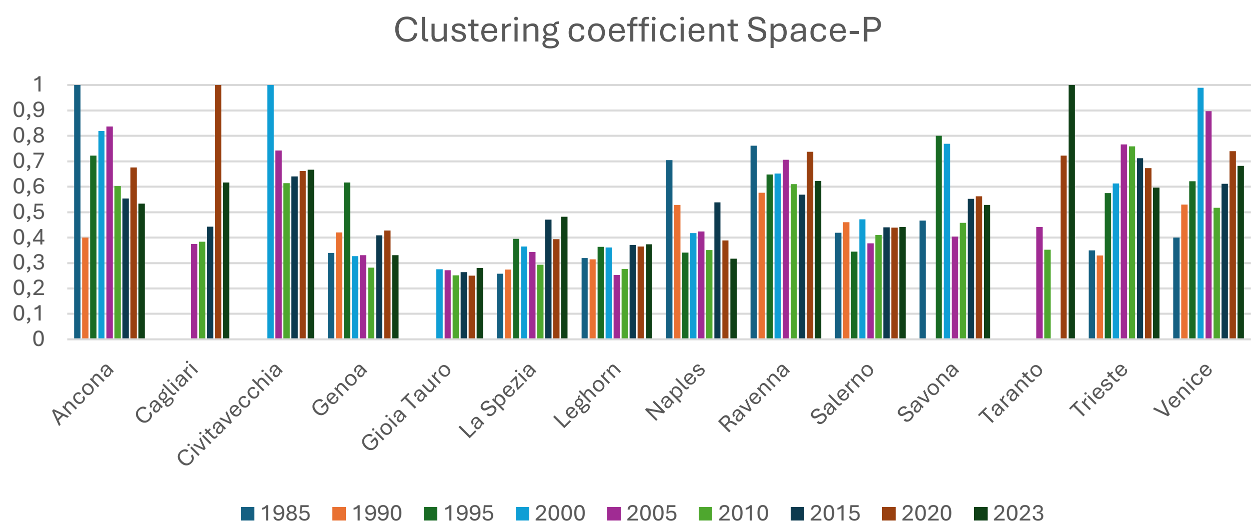



*Figure 33 Clustering coefficient Space-P*

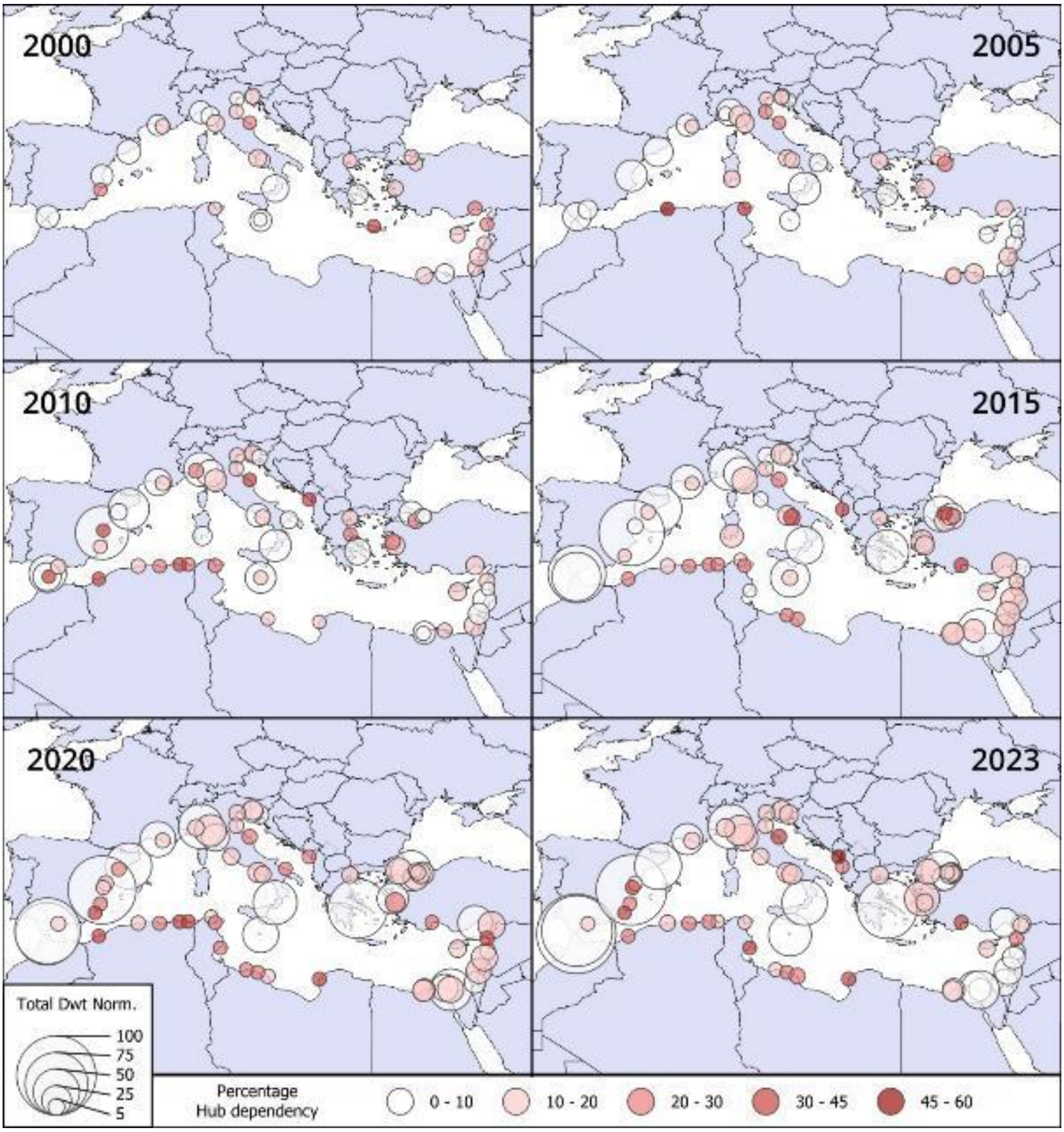



This strong regionalization of Adriatic ports is also suggested by the values of the clustering coefficient showed in Figure 32 and Figure 33. This measure indicates the extent to which ports directly connected to a given port are also interconnected among themselves, thereby suggesting the presence of a denser regional network structure.

### 3.4.4. Hub dependence

Figure 34 illustrates the level of hub dependency of Mediterranean ports within a hub-based network. This indicator was not calculated on the basis of direct port-to-port connections, but rather by considering the set of ports indirectly connected through vessels that called at the port during the year under analysis.

*Figure 34 Percentage of hub traffic at Mediterranean ports and total deadweight tonnage (DWT) transiting through them*



Reconstructing hub dependency exclusively through direct connections presents important methodological limitations in the context of container maritime transport. Shipping services, including feeder services, are typically organised through rotations that involve multiple port calls within a single service loop. Consequently, the analysis of direct links alone may fail to accurately capture the hub-and-spoke dynamics that characterise container shipping networks.

For example, in the case of ports such as Genoa, an analysis of direct connections reveals a strong concentration of links with nearby ports such as Livorno, or Trieste with a high number of direct connection with Koper or Rijeka. However, this pattern does not necessarily reflect a hub-and-spoke relationship associated with transshipment activities. Instead, it is more likely to indicate a high level of integration between the two ports within shared maritime service networks.

Moreover, the lack of detailed historical information regarding the actual configuration of shipping companies' service networks makes it necessary to adopt an analytical methodology capable of approximating these inter-port relationships. To address this limitation, and following the same logic used to construct the SpaceP network at the global scale, vessels that called at both the port under analysis and one or more hub ports within the same year were classified as "hub vessels". Conversely, vessels that did not call at any hub port were classified as "non-hub vessels."

Based on this classification, the deadweight tonnage (DWT) of hub vessels and non-hub vessels was aggregated annually, and the share of hub vessels relative to the total was calculated. This indicator therefore provides an approximation of the extent to which the cargo-carrying capacity passing through a port can be considered dependent on commercial flows routed through hub ports.

The list of Mediterranean hub ports used for this classification was defined on the basis of both the results of the betweenness centrality analysis and the relevant literature on the subject (Notteboom, 1997; Notteboom, 2010; Notteboom et al., 2014; Ivona, 2010). This decision was made in order to take into account certain hub port projects that lasted for only a short period of time, such as those in Cagliari and Taranto, which, as the analysis shows, did not record high levels of betweenness centrality.

Figure 34 presents two types of information simultaneously. On the one hand, it displays the hub dependency indicator calculated as described above. On the other hand, it shows the total DWT of vessels calling at Mediterranean ports, normalised with respect to the highest value in the series (Tangier Med in 2023) and represented by the size of the circles in the figure.

Observing these two elements together reveals two broad patterns that remain relatively consistent over time. First, as expected, ports exhibiting the highest levels of hub dependency and represented by larger circles are, in the vast majority of cases, ports with relatively low total DWT volumes. Conversely, ports handling the largest total DWT volumes generally show lower percentages of flows linked to hub ports.

Second, over the period analysed, an increase in total DWT can be observed in the main Mediterranean ports. This trend can likely be attributed both to the growing concentration of cargo in major load centres and hub ports and to the increase in vessel sizes, which has led shipping companies to concentrate port calls in a limited number of strategic locations.

From a geographical perspective, clear regional differences also emerge. Ports located in North Africa, particularly in Algeria, Tunisia and Libya, tend to display higher levels of hub dependency compared with other areas of the Mediterranean. This finding confirms earlier results by Mohamed-Chérif and Ducruet (2016), who identified a stronger dependence of ports in this region on connections with hub ports.

A certain degree of hub dependency can also be observed among ports in the Adriatic Sea, particularly among smaller ports such as Ancona. Finally, among the ports classified as hubs, Cagliari appears to be the only one that in 2005 and 2015 recorded more than 10% of traffic associated with other Mediterranean hub ports, suggesting the presence of relay or inter-hub transshipment dynamics during those years.

Overall, a relationship can be observed between the cargo-carrying capacity handled by a port during the year and its level of hub dependency. This relationship was tested through the Spearman rank correlation coefficient, which was used to evaluate the association between these two variables.

The Spearman correlation coefficient (Spearman's ρ) is a non-parametric measure of association between two ordinal or quantitative variables that do not necessarily follow a normal distribution. It assesses the strength and direction of a monotonic relationship between variables by relying on the ranks of the data rather than their original values. Because it does not require assumptions of linearity or normality, the Spearman correlation is particularly suitable in the presence of skewed distributions or outliers.

The coefficient ranges between −1 and +1: values close to +1 indicate a strong positive monotonic relationship, values close to −1 indicate a strong negative monotonic relationship, while values near 0 suggest the absence of a monotonic association. The p-value indicates the statistical significance of the relationship; values below 0.05 are generally considered statistically significant and unlikely to result from random variation.

Figure 35 presents a scatter plot for Mediterranean ports excluding hub ports, where total DWT is plotted on the vertical axis and the percentage of hub dependency on the horizontal one. When considering the full dataset across the years analysed, the correlation reveals a negative relationship with a Spearman coefficient greater than 0.5, indicating that ports handling larger cargo volumes tend to display lower levels of hub dependency.

However, when the analysis is conducted separately for individual years, as illustrated in Figure 36, the evolution of this relationship emerges. In 2000, despite relatively low levels of hub dependency across most ports, the correlation already showed a Spearman coefficient above −0.6, suggesting a clear inverse relationship between throughput and dependency.

In 2005, the correlation temporarily weakened, with the coefficient decreasing to around −0.2, even though some ports experienced increasing levels of hub dependency. This suggests a phase of greater heterogeneity in the relationship between traffic volumes and dependency levels.

From 2010 onwards, the relationship became progressively stronger again, with correlation values exceeding −0.7 and reaching levels above −0.8 by 2020. This trend indicates a growing structural differentiation within the Mediterranean port system, where ports with higher traffic volumes increasingly operate as more autonomous nodes within the network, while smaller ports tend to remain more strongly dependent on hub connections.

These results are consistent with the hierarchical organisation typically observed in hub-and-spoke maritime networks, where a limited number of large ports concentrate direct connections and traffic flows, while smaller ports rely on indirect access through hub ports.

From this perspective, the strengthening of the negative correlation over time indicates an increasing functional differentiation between major Mediterranean loading centres and peripheral feeder ports. At the same time, this confirms the persistence of structural asymmetries within the regional maritime system, in which access to global shipping networks is still largely dependent on a small number of dominant hub ports.

*Figure 35 Spearman correlation Total DWT all the years*

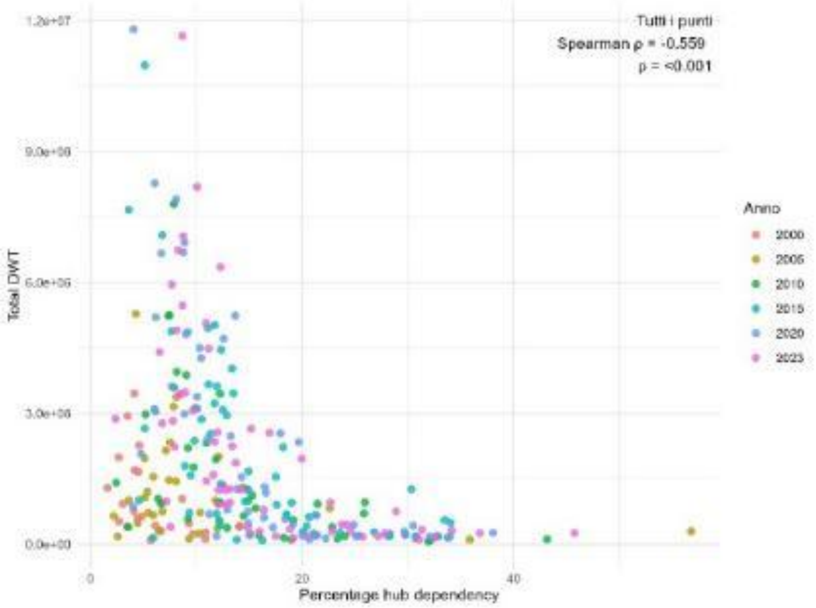
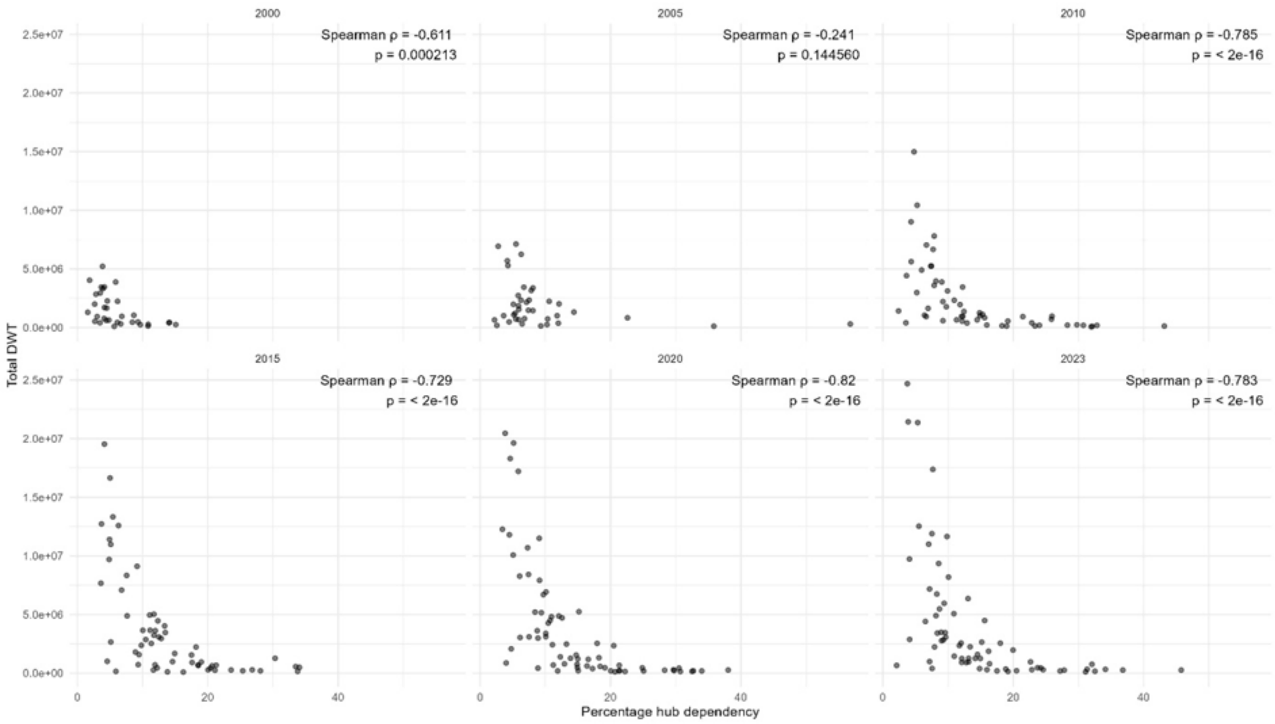


*Figure 36 Spearman correlation DWT annually*

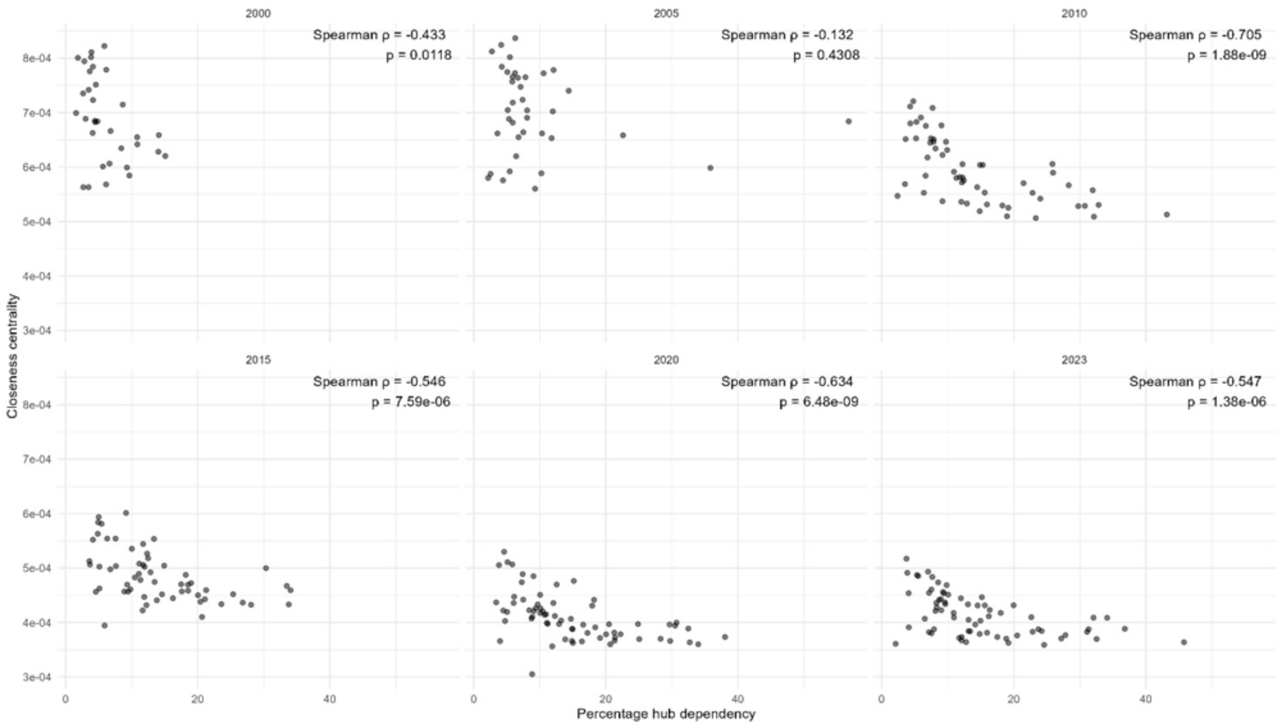



To further explore the relationship between hub dependency and the structural position of ports within the maritime network, hub dependency values were correlated with several Space-P centrality measures, including closeness centrality, eigenvector centrality, node degree and betweenness centrality.

Figure 37 shows the results of this comparison and indicates that the strongest relationship emerges between hub dependency and closeness centrality. In particular, the correlation between these two variables becomes more pronounced from 2010 onwards.

This result suggests that ports exhibiting higher levels of hub dependency tend to occupy positions that are less central within the global maritime network, as reflected by lower levels of closeness centrality. Since closeness centrality captures the average proximity of a node to all other nodes in the network, lower values indicate a more peripheral position within the system. Moreover, the data appear to indicate a general trend towards the peripheralisation of Mediterranean ports, as reflected in the overall decline in closeness centrality values over time. This pattern may suggest a gradual reduction in the relative centrality of Mediterranean ports within the global maritime network, potentially linked to broader changes in global shipping routes, the increasing dominance of a limited number of major hub ports, and the reorganisation of liner service networks.

*Figure 37 Spearman correlation Closeness centrality annually*




Both eigenvector centrality and node degree, presented in Figure 38 and Figure 39 respectively, show a more significant relationship with hub dependency in the years 2010, 2020 and 2023.

The correlation with eigenvector centrality broadly confirms that ports exhibiting higher levels of hub dependency tend to be less connected to highly influential nodes within the network, except for their reference hub ports. This suggests that such ports maintain connections that are primarily regional in nature, relying on hub-mediated links rather than on direct integration with other central ports in the network.

The relationship with node degree, on the other hand, indicates that ports characterised by higher hub dependency generally maintain a lower number of direct connections with other ports. This finding is consistent with the observations of Ducruet et al. (2010), who highlighted how ports with higher dependency within hub-and-spoke systems tend to display reduced levels of direct connectivity. However, in this case the relationship appears less pronounced than that observed for eigenvector centrality.

Finally, when considering betweenness centrality (Figure 40), the relationship with hub dependency appears significant only in 2010 and 2020, when the Spearman coefficient exceeds 0.5. This result may be influenced by the presence of certain gateway ports that display relatively high betweenness values while simultaneously maintaining structured connections with major hub ports. In such cases, these ports may still perform intermediary functions within regional or subregional flows despite showing some degree of hub dependency. The weaker and more variable relationship observed for betweenness centrality indicates that some ports may still perform intermediate functions within regional or subregional flows, even when they remain structurally dependent on hub ports for access to global shipping networks.

*Figure 38 Spearman correlation Eigenvector centrality annually*

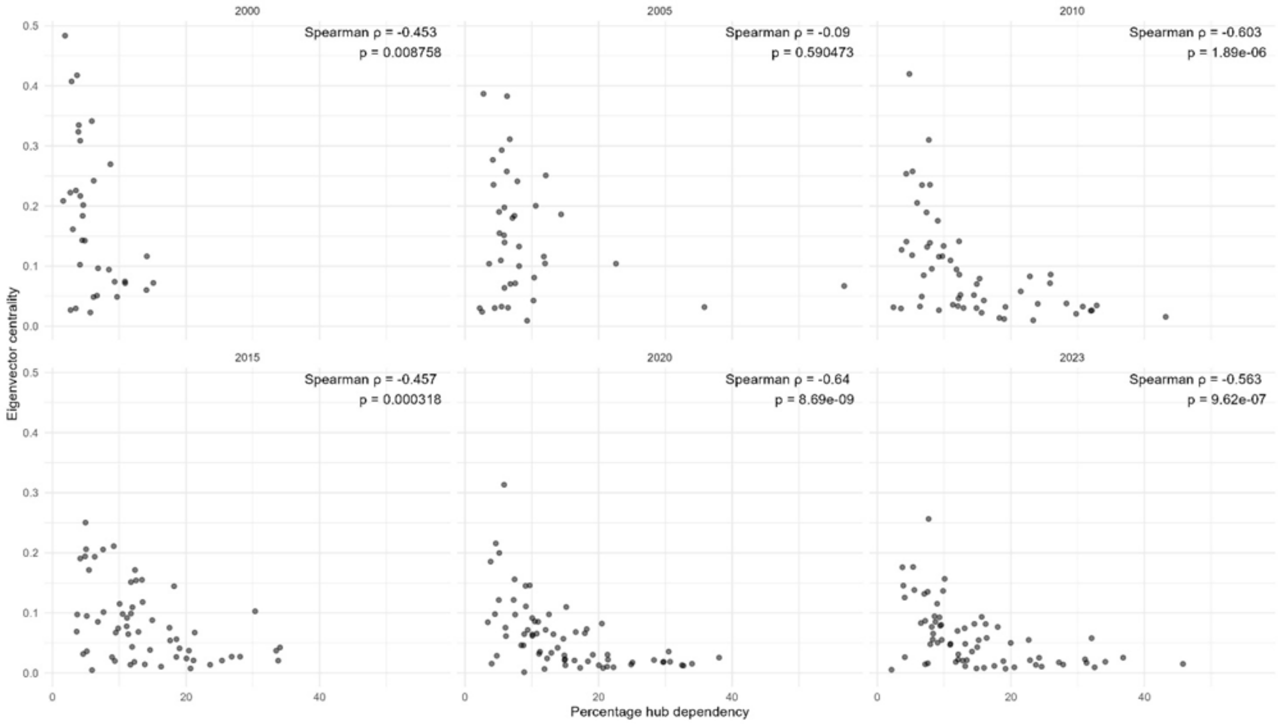



*Figure 39 Spearman correlation Node degree annually*

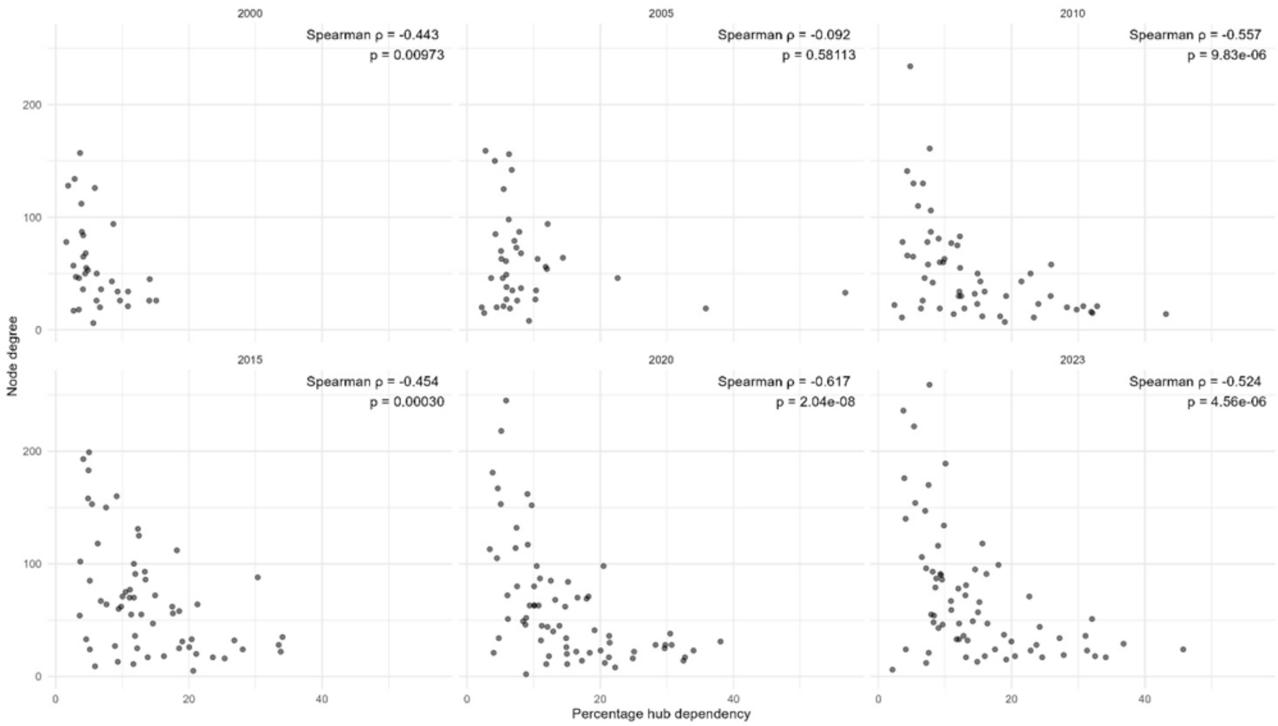
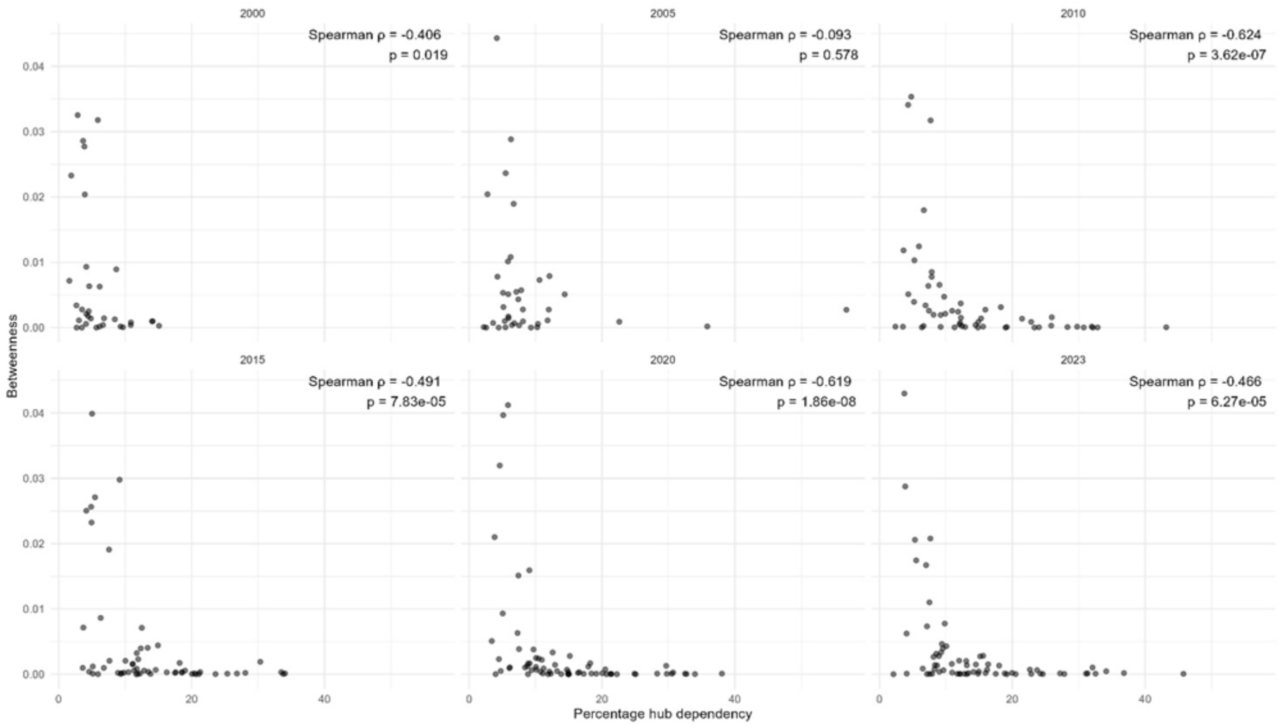
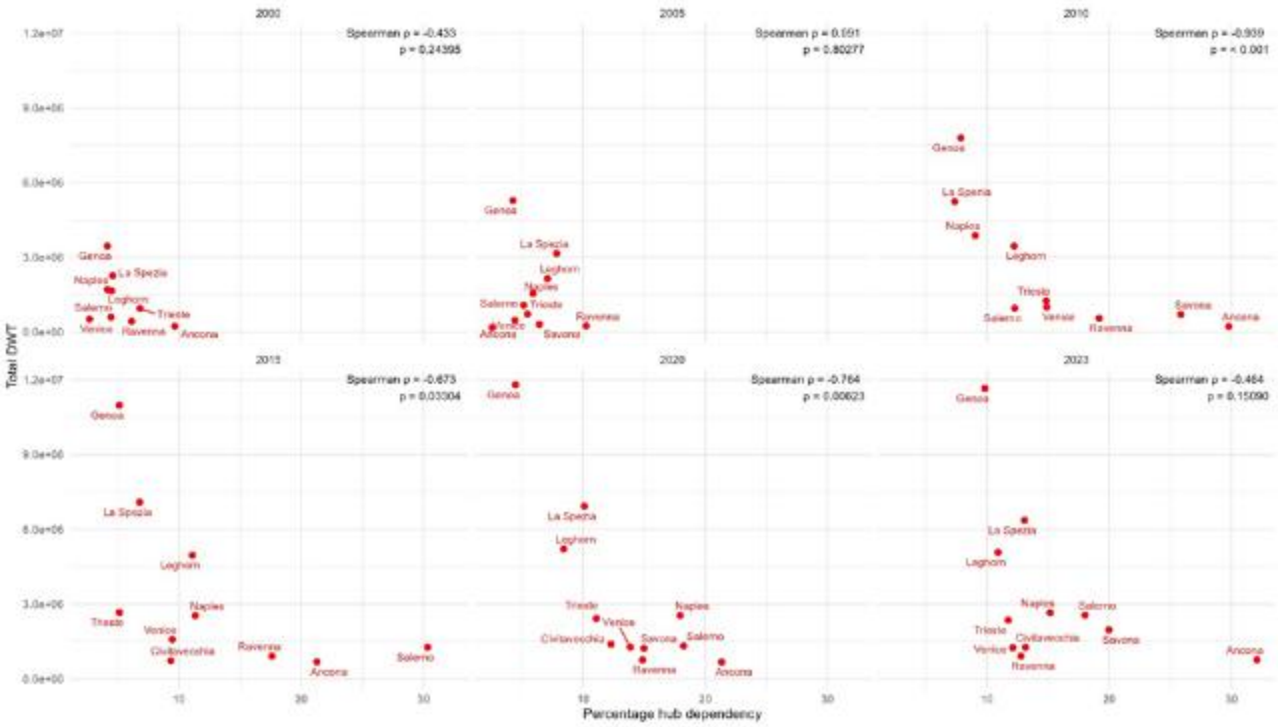


*Figure 40 Spearman correlation Betweenness annually*




If we look at Italian ports, however, there is a correlation only in terms of Total DWT, which was very strong in 2010 and remained high in 2015 and 2020, as shown in Figure 41. By 2023, however, this correlation becomes weaker.

*Figure 41 Spearman correlation Total DWT of italian ports*



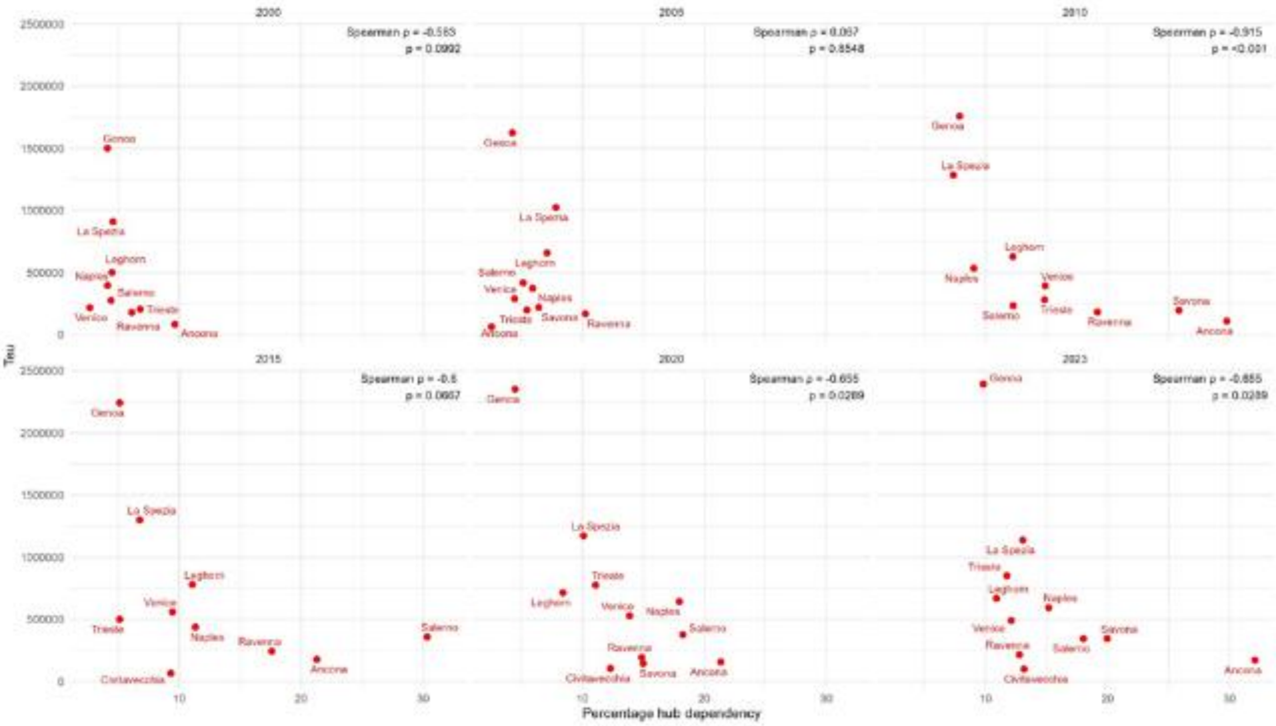

When considering the container traffic handled by Italian ports, based on data provided by Assoporti, a clear relationship also emerges between TEU throughput and the percentage of hub dependency.

Figure 42 shows that the correlation appears particularly strong in 2010, when the Spearman coefficient reaches ρ −0.915, indicating a very strong negative association between the two variables. In the subsequent years analysed, the relationship remains significant, with correlation values consistently above −0.6.

While the relationship observed with total DWT may appear relatively intuitive, since ports that are more strongly integrated into feeder services are likely to receive smaller vessels compared with ports served by direct mainline connections, the existence of a similarly strong relationship with TEU traffic volumes is less obvious. In principle, the size of vessels calling at a port does not necessarily correspond directly to the overall commercial flows handled by that port.

These results suggest that hub dependency is not only associated with differences in vessel size and service structure, but also reflects broader differences in the commercial role of ports within maritime transport networks. In particular, the evidence indicates that Italian ports capable of generating higher volumes of container traffic tend to maintain lower levels of hub dependency. In other words, ports handling larger TEU flows appear to rely less on indirect connections mediated by hub ports and are more likely to be integrated directly into international liner service networks. Nevertheless, some ports appear to deviate from this general pattern. In particular, Civitavecchia during the last three years of analysis and Ravenna in the final two years show values that do not fully conform to this relationship, suggesting the presence of distinct functional characteristics within the Italian port system. These cases may reflect specific local dynamics, such as the role of niche services, regional logistics functions, or evolving service patterns within liner shipping networks.

*Figure 42 Spearman correlation with TEU traffic of italian ports*




## 3.4.5. Maritime Network vulnerability

Figure 43 presents a targeted attack simulation on the global maritime Space-P network, in which nodes (ports) are progressively removed according to their betweenness centrality. In order to assess the vulnerability of the network after each node removal, the analysis measures how many nodes remain connected to the giant component, defined as the largest group of mutually connected nodes within the network.

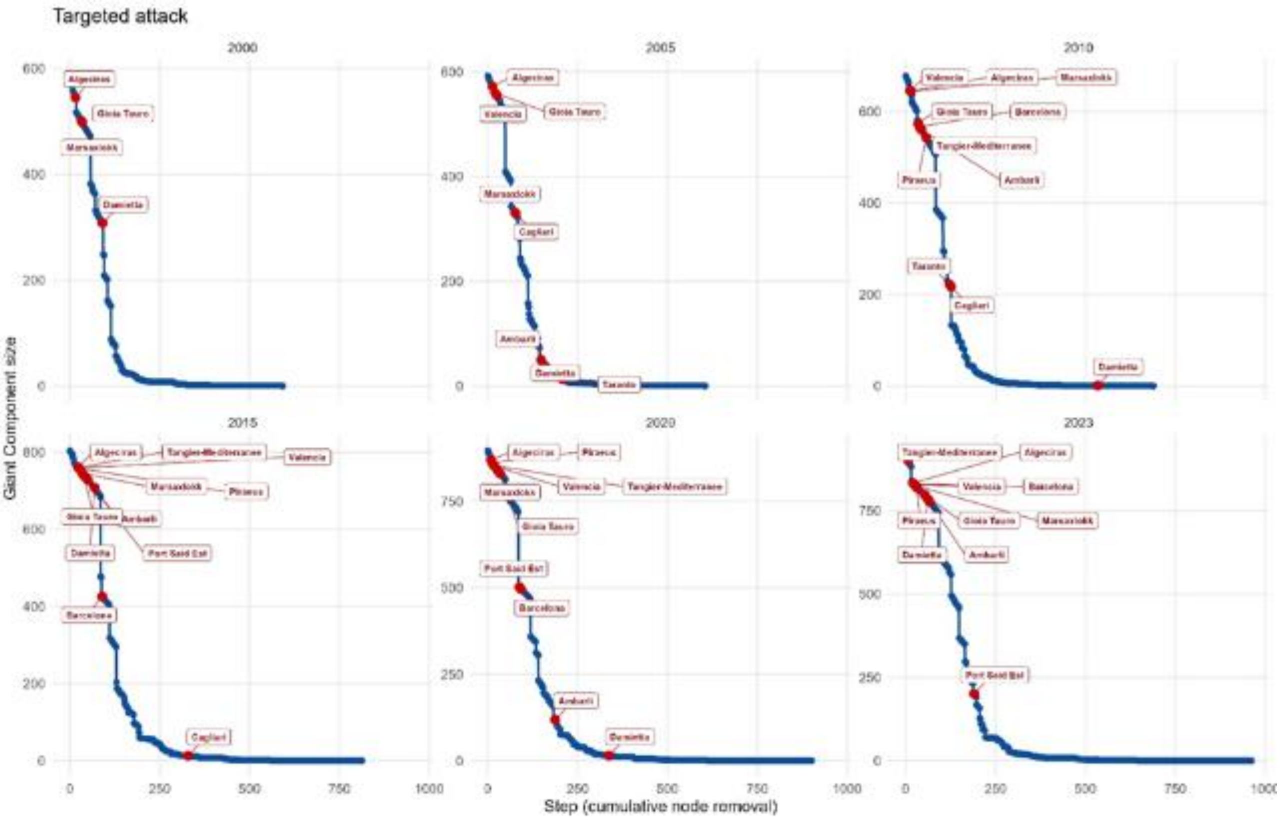
As shown in the figure, when nodes with the highest betweenness centrality are removed first, the size of the giant component decreases rapidly. This result confirms the well-known vulnerability of scale-free networks to targeted attacks on highly central nodes. Because such nodes play a key intermediary role in connecting different parts of the network, their removal quickly fragments the system and significantly reduces overall connectivity.

The results also show that many Mediterranean hub ports occupy increasingly high positions in terms of betweenness centrality over the years, highlighting their growing importance as intermediary nodes within the global maritime network.

Figure 44 compares the results across different years by plotting them within the same graph and normalising the size of the giant component along the y-axis, allowing the speed of network fragmentation (percolation) to be directly compared. Although the curves remain relatively steep, indicating that the network is still sensitive to targeted attacks, a progressive shift of the curves toward the right can be observed.

This shift suggests that the network has become slightly more resilient over time, as a larger number of node removals is required before the giant component begins to collapse. In other words, while the global maritime network retains the structural characteristics of a scale-free system, its topology appears to have evolved toward a configuration that slows down the process of fragmentation under targeted disruptions.

*Figure 43 Targheting attack on Global maritime network (Space-P). Mediterranean Hub Ports in red.*



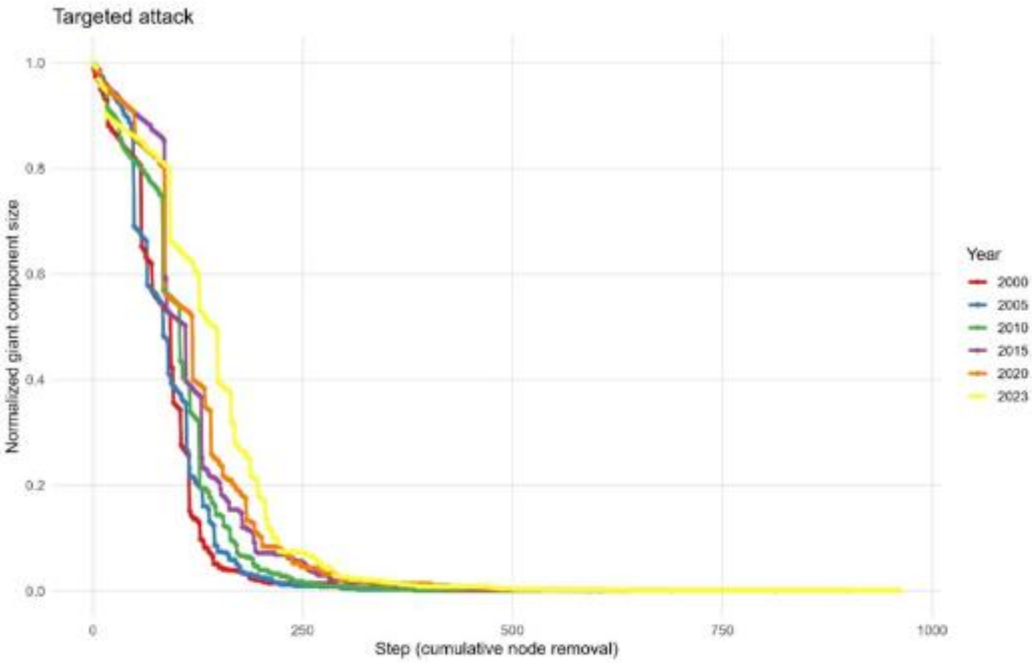

In order to assess the resilience of the Italian port system, a filtered network was reconstructed for each port starting from the global Space-P maritime network. This type of network, commonly referred to as an ego-network, is defined as a subnetwork extracted according to the topological distance between a focal node (or group of nodes) and the rest of the network. In the case of national-level analysis, the ego-network is constructed around a group of nodes (all ports belonging to a specific country), while in port-level analysis it is centred on a single node.

Determining the appropriate topological distance to use when filtering ports from the global maritime network is not straightforward. In this chapter, the analysis focuses on connections within a distance of two edges, corresponding to a potential transshipment operation between two vessels or maritime services. This approach is consistent with the logic of the inner and outer maritime rings introduced in the pioneering study on hub dependency in North Korea by Ducruet (2008).

Figure 45 shows the ego-network extracted using all Italian ports, excluding the national hub ports Gioia Tauro, Cagliari and Taranto. This network is then subjected to a targeted attack simulation, in which nodes are progressively removed according to their betweenness centrality. In order to compare different years, the size of the giant component (GC) has been normalised.

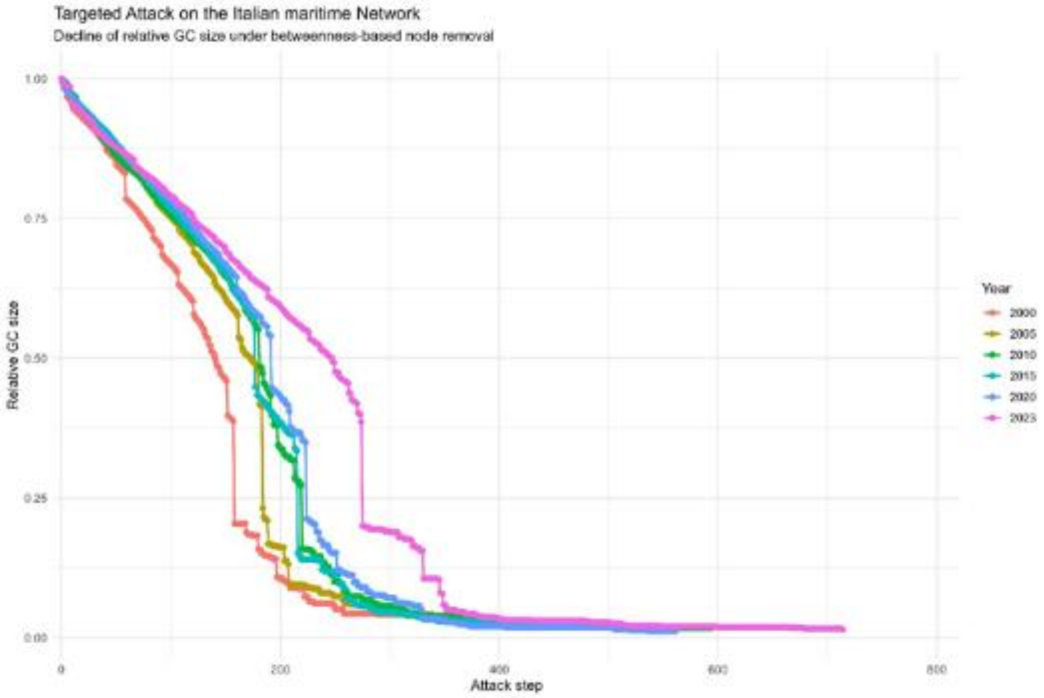
As shown in the figure, the Italian maritime network appears more fragile in 2000, when the percolation process occurs more rapidly and the giant component breaks down after relatively few node removals. This indicates a higher level of structural vulnerability at that time.

*Figure 44 Comparison between the targheting attack on Global Shipping Network in different years with normalized giant component*




From 2010 to 2020, however, the curves shift progressively towards the right, suggesting a greater ability of the network to resist the initial fragmentation of the giant component. In other words, a larger number of node removals is required before a significant disruption of connectivity occurs.

*Figure 45 Comparison between the targheted attack on Italian Shipping Network in different years with normalized giant component*




Finally, the curve shifts even further to the right in 2023, where the first significant break in the giant component occurs later than in the previous years. This pattern suggests a reduction in the vulnerability of the Italian maritime network, potentially reflecting structural adjustments that occurred in the aftermath of the COVID-19 crisis in 2020, which led to significant reorganisations in global shipping networks and port connectivity patterns.

To analyse the vulnerability of the networks reconstructed around individual Italian ports, several aspects were considered. Figure 46 presents the density of the different ego-networks associated with each port. Network density has often been linked in the literature to the concept of redundancy, defined as the capacity of a network to provide alternative paths when a node is removed.

As shown in Figure 46, Adriatic ports exhibit higher network density over time compared with ports located along the Tyrrhenian coast, although some exceptions can be observed in specific years, such as Salerno and Savona in 2010, Savona in 2020, and Civitavecchia in 2023. This pattern may partly reflect the fact that many of these ports are embedded in predominantly Mediterranean maritime networks, which, as already observed by McCalla et al. (2004), tend to display relatively high levels of network density.

However, analysing network density alone does not fully capture the vulnerability of the focal port within its own network. For this reason, an additional measure was introduced to evaluate how quickly a port becomes isolated within its ego-network when the network is subjected to targeted disruptions.

Specifically, the analysis measures the relative speed at which the focal node becomes isolated—that is, when its degree becomes equal to zero—during a targeted attack simulation based on betweenness centrality. To quantify this relative speed of isolation, the number of steps required to completely isolate the port is calculated and expressed relative to the total number of nodes in the network.

Figure 47 illustrates the evolution of this isolation speed over time. Higher values indicate that the port becomes isolated more rapidly within the network. As the results show, a high level of network density does not necessarily correspond to lower vulnerability for the focal port. In several cases, ports embedded in relatively dense networks still become isolated rapidly when central nodes are removed. At the same time, this pattern does not appear to follow a consistent trend across all ports and years, suggesting that the relationship between network density, redundancy and node vulnerability may be more complex than expected within the Italian maritime port system.

*Figure 46 Density of ego-networks of Italian ports.*

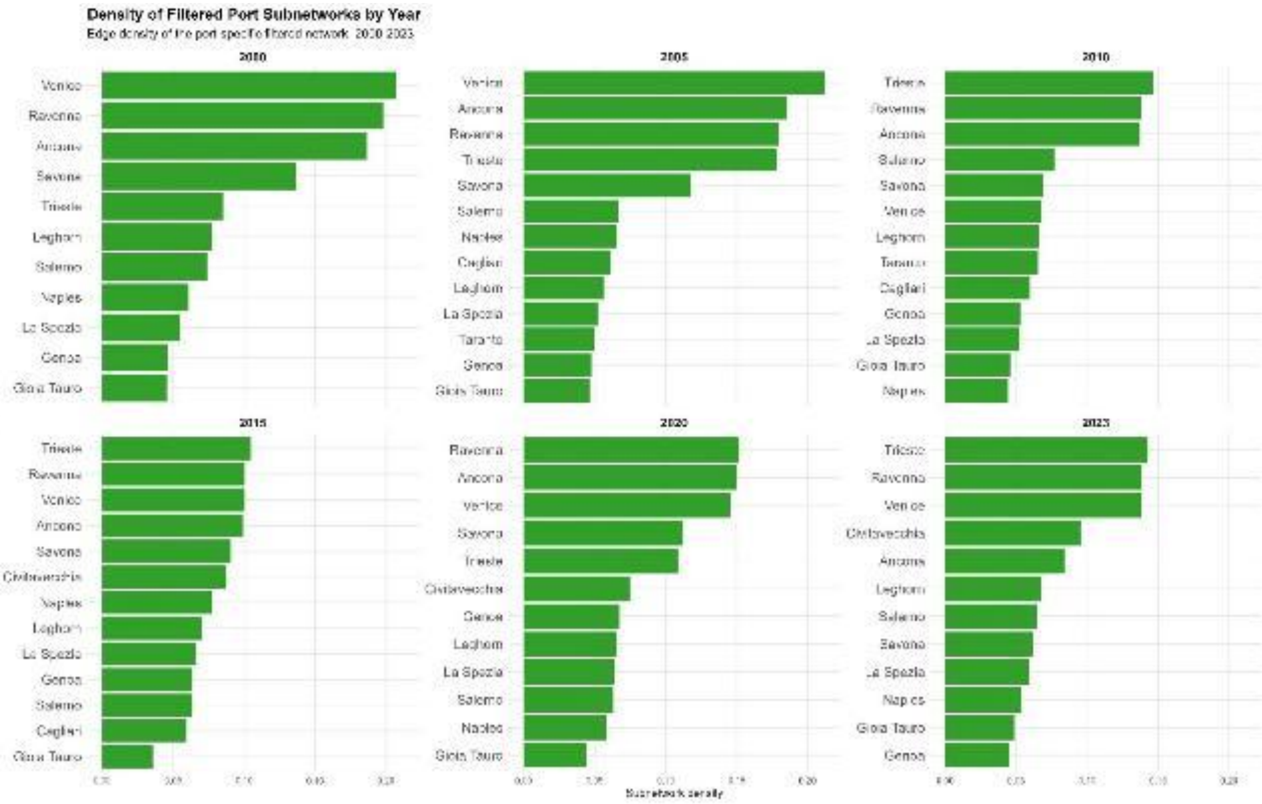
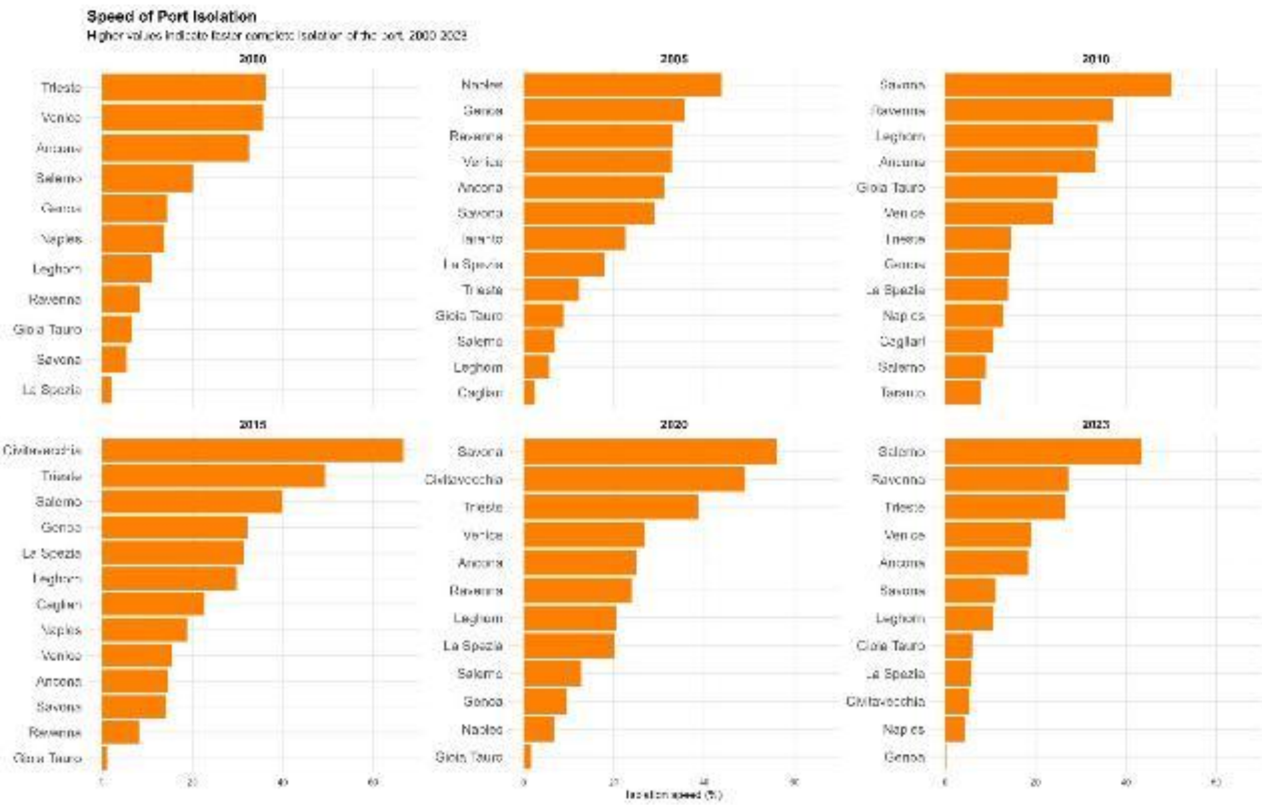



*Figure 47 Speed of port isolation*



Finally, an additional analysis examined which Mediterranean hub ports, when removed from the global Space-P maritime network, produce the greatest impact on Italian ports, both in terms of Closeness centrality and Eigenvector centrality.

*Table 10 Most impacting hub on closeness centrality of italian ports*

| PORT | 2000 | 2005 | 2010 | 2015 | 2020 | 2023 |
|---|---|---|---|---|---|---|
| **Ancona** | Marsaxlokk (-0.002) | Gioia Tauro (-0.008) | Marsaxlokk (-0.007) | Algeciras (-0.009) | Piraeus (-0.003) | Gioia Tauro (-0.002) |
| **Civitavecchia** | | | | Gioia Tauro (-0.007) | Algeciras (-0.002) | Tangier-Med (-0.006) |
| **Genoa** | Algeciras (-0.003) | Algeciras (-0.002) | Algeciras (-0.002) | Tangier-Med (-0.002) | Tangier-Med (-0.001) | Barcelona (-0.001) |
| **La Spezia** | Gioia Tauro (-0.001) | Gioia Tauro (-0.001) | Gioia Tauro (-0.001) | Ambarli (-0.001) | Algeciras (-0.001) | Algeciras (-0.001) |
| **Leghorn** | Valencia (-0.003) | Algeciras (-0.002) | Algeciras (-0.003) | Gioia Tauro (-0.001) | Piraeus (-0.001) | Algeciras (-0.003) |
| **Naples** | Valencia (-0.003) | Barcelona (-0.002) | Algeciras (-0.002) | Gioia Tauro (-0.004) | Tangier-Med (-0.001) | Algeciras (-0.003) |
| **Ravenna** | Gioia Tauro (-0.005) | Gioia Tauro (-0.007) | Marsaxlokk (-0.008) | Algeciras (-0.009) | Gioia Tauro (-0.005) | Gioia Tauro (-0.003) |
| **Salerno** | Valencia (-0.004) | Algeciras (-0.006) | Algeciras (-0.003) | Algeciras (-0.002) | Piraeus (-0.002) | Algeciras (-0.002) |
| **Savona** | | Barcelona (-0.004) | Marsaxlokk (-0.002) | | Tangier-Med (-0.008) | Tangier-Med (-0.005) |
| **Trieste** | Valencia (-0.007) | Gioia Tauro (-0.006) | Piraeus (-0.003) | Gioia Tauro (-0.005) | Gioia Tauro (-0.004) | Marsaxlokk (-0.003) |
| **Venice** | Gioia Tauro (-0.005) | Piraeus (-0.005) | Valencia (-0.005) | Algeciras (-0.009) | Piraeus (-0.003) | Marsaxlokk (-0.002) |

From Table 10, it can be observed that the gateway ports along the Tyrrhenian coast, such as Genoa, La Spezia, and Livorno, generally experience lower impacts on closeness centrality when the most influential hub port is removed from the network compared with other Italian ports. Among these, La Spezia appears to be the least affected port.

Similarly, Naples and Salerno tend to display relatively lower values of reduction, with some exceptions, namely Naples in 2015, which records a reduction of −0.004, and Salerno in 2000 and 2015.

Smaller Tyrrhenian ports such as Civitavecchia and Savona, by contrast, show higher peak values of reduction compared with other ports along the same coast. In 2023, both ports appear to be strongly affected by the removal of Tangier Med.

Adriatic ports, including Ancona, Trieste, Ravenna, and Venice, display higher average reduction values at least until 2015. However, in 2020 and 2023, these ports show lower levels of impact.

This pattern suggests that the geographical position of Adriatic ports has historically represented a factor of vulnerability within the hub-and-spoke system, although the results observed in the last two years of the analysis indicate a possible reduction in this vulnerability.

Table 11 identifies the hub ports whose removal produces the largest reduction in the eigenvector centrality of Italian ports. This analysis provides insight into which external hubs exert the greatest influence on the network integration of Italian ports within the global maritime system.

For Tyrrhenian ports in the period 2000–2005, the removal of the Spanish ports of Valencia and Barcelona generated the most significant reductions in eigenvector centrality, with the exception of Salerno, which follows a different pattern. For Adriatic ports, by contrast, the port exerting the greatest influence during this period was Piraeus.

In 2010, Valencia emerges as the port whose removal has the most substantial impact on the eigenvector centrality of almost all Italian ports, highlighting its growing importance within Mediterranean and global shipping networks.

From 2015 onwards, however, Piraeus becomes the hub port whose removal produces the largest impact on the network centrality of Italian ports. This shift is likely linked to the strengthening of Piraeus as a major transshipment hub connecting the Mediterranean to Asian shipping routes, particularly following the development of its container terminal operated by the Chinese shipping company COSCO Shipping. The expansion of these connections significantly increased the strategic role of Piraeus within east-west maritime corridors and, consequently, its influence on the connectivity patterns of several Mediterranean ports, including those in Italy.

*Table 11 Most impacting hub on eigenvector centrality*

| PORT | 2000 | 2005 | 2010 | 2015 | 2020 | 2023 |
|---|---|---|---|---|---|---|
| **Ancona** | Piraeus (-0.02) | Piraeus (-0.011) | Marsaxlokk (-0.005) | Piraeus (-0.022) | Piraeus (-0.02) | Piraeus (-0.016) |
| **Civitavecchia** | | | | Gioia Tauro (-0.004) | Piraeus (-0.008) | Tangier-Med (-0.004) |
| **Genoa** | Barcelona (-0.059) | Barcelona (-0.043) | Valencia (-0.064) | Piraeus (-0.019) | Piraeus (-0.039) | Piraeus (-0.038) |
| **La Spezia** | Valencia (-0.045) | Valencia (-0.035) | Valencia (-0.045) | Valencia (-0.018) | Piraeus (-0.023) | Piraeus (-0.022) |
| **Leghorn** | Valencia (-0.055) | Valencia (-0.049) | Valencia (-0.058) | Piraeus (-0.017) | Piraeus (-0.02) | Piraeus (-0.012) |
| **Naples** | Valencia (-0.056) | Barcelona (-0.023) | Valencia (-0.037) | Piraeus (-0.015) | Piraeus (-0.024) | Piraeus (-0.014) |
| **Ravenna** | Piraeus (-0.025) | Piraeus (-0.021) | Gioia Tauro (-0.01) | Piraeus (-0.017) | Piraeus (-0.018) | Piraeus (-0.008) |
| **Salerno** | Piraeus (-0.039) | Piraeus (-0.027) | Valencia (-0.022) | Piraeus (-0.026) | Piraeus (-0.024) | Piraeus (-0.026) |
| **Savona** | | Valencia (-0.01) | Valencia (-0.028) | | Algeciras (-0.011) | Piraeus (-0.008) |
| **Trieste** | Piraeus (-0.023) | Piraeus (-0.012) | Gioia Tauro (-0.008) | Piraeus (-0.011) | Piraeus (-0.017) | Piraeus (-0.005) |
| **Venice** | Piraeus (-0.011) | Piraeus (-0.016) | Valencia (-0.014) | Piraeus (-0.027) | Piraeus (-0.027) | Piraeus (-0.012) |

## 3.5 Discussion

The results presented in this chapter highlight several structural characteristics of the Italian port system within the global maritime network. Taken together, the analyses of hub dependency, centrality measures and network vulnerability reveal a system that remains strongly embedded within the hierarchical structure of Mediterranean hub-and-spoke networks.

The strong hierarchical organization of Mediterranean maritime networks, illustrated in Figure 22, appears to have become particularly pronounced in 2010 and in the most recent years of the analysis (2020 and 2023). In the latter period, the Mediterranean system shows a clearer geographical polarization, structured around two main hub clusters. In the western Mediterranean, the hub system is concentrated around the Algeciras and Tangier Med, which appear to compete directly with each other and are complemented by the important role of Valencia. In the eastern Mediterranean, the system is increasingly centered around the Piraeus. Between these two poles, other Mediterranean hub ports such as Gioia Tauro and Marsaxlokk maintain important hub functions, although with comparatively lower levels of betweenness centrality.

Parallel to this process, the analysis reveals the emergence of groups of ports characterized by different levels of hub dependency. The primary factor explaining these differences appears to be the ability of ports to concentrate large traffic volumes and attract larger vessels, although specific geographical patterns also play a role. At the Mediterranean scale, the North African coastline tends to display generally higher levels of hub dependency. A similar pattern can also be observed in the Adriatic Sea region, where several ports appear particularly sensitive to hub-mediated connectivity. This geographical pattern partially reflects the regionalization of maritime connections, with some port systems remaining strongly embedded within regional shipping networks.

The observed correlation between hub dependency and both DWT and TEU traffic volumes suggests that Italian ports capable of generating larger commercial flows tend to maintain lower levels of dependency on external hub ports. These ports are more likely to be directly integrated into international liner service networks, while smaller ports remain more strongly connected through feeder services and indirect routes. At the same time, the presence of some exceptions, such as Civitavecchia and Ravenna in the most recent years of the analysis, suggests that functional diversification within the Italian port system may lead certain ports to deviate from this general pattern.

The analysis of network centrality measures further confirms the existence of a structural differentiation between more central and more peripheral ports. Higher levels of hub dependency are generally associated with lower values of closeness centrality, eigenvector centrality and node degree, indicating a more peripheral position within the global maritime network. The weaker relationship observed with betweenness centrality suggests that some ports may still perform intermediary roles within regional maritime flows, even when they remain structurally dependent on major hubs.

More broadly, the analysis of betweenness centrality within the Mediterranean network highlights the growing importance of several hub ports as key intermediary nodes connecting regional and global maritime routes. The increasing betweenness values observed for many Mediterranean hub ports over time suggest that these nodes play an increasingly critical role in maintaining the connectivity of the wider maritime system. As shown by the targeted attack simulations, the removal of ports with high betweenness leads to a rapid fragmentation of the global network, confirming the vulnerability of scale-free maritime systems to disruptions affecting key intermediary hubs.

The vulnerability analysis based on targeted attack simulations also reveals how the resilience of maritime networks depends strongly on the presence of highly central nodes. While the global Space-P network shows the typical vulnerability of scale-free systems to targeted disruptions, the Italian maritime network appears to have become progressively more resilient over time, as indicated by the slower fragmentation of the giant component in more recent years. Nevertheless, the ego-network analysis demonstrates that high network density does not necessarily guarantee lower vulnerability for individual ports, since some nodes become isolated rapidly even when embedded in relatively dense local networks.

Finally, the analysis of the external hubs influencing Italian port connectivity highlights the growing strategic role of major Mediterranean transshipment ports. In particular, the increasing influence of the Port of Piraeus in recent years reflects the restructuring of east-west maritime routes and the strengthening of connections with Asian shipping networks following investments by COSCO Shipping. This shift illustrates how changes in global shipping strategies and terminal investments can reshape the connectivity patterns of national port systems.

*Table 12 Summary table of Spearman's correlations between hub dependency values of Mediterranean Ports and the other variables*

| Variables | 2000 | 2005 | 2010 | 2015 | 2020 | 2023 |
|---|---|---|---|---|---|---|
| **Betweenness** | $\rho = -0.406$, $p = 0.019$ | $\rho = -0.093$, $p = 0.578$ | $\rho = -0.624$, $p = 3.62e-07$ | $\rho = -0.491$, $p = 7.83e-05$ | $\rho = -0.619$, $p = 1.86e-08$ | $\rho = -0.466$, $p = 6.27e-05$ |
| **Closeness centrality** | $\rho = -0.433$, $p = 0.0118$ | $\rho = -0.132$, $p = 0.4308$ | $\rho = -0.705$, $p = 1.88e-09$ | $\rho = -0.546$, $p = 7.59e-06$ | $\rho = -0.634$, $p = 6.48e-09$ | $\rho = -0.547$, $p = 1.38e-06$ |
| **Eigenvector centrality** | $\rho = -0.453$, $p = 0.008758$ | $\rho = -0.090$, $p = 0.590473$ | $\rho = -0.603$, $p = 1.89e-06$ | $\rho = -0.457$, $p = 0.000318$ | $\rho = -0.640$, $p = 8.69e-09$ | $\rho = -0.563$, $p = 9.62e-07$ |
| **Node degree** | $\rho = -0.443$, $p = 0.00973$ | $\rho = -0.092$, $p = 0.58113$ | $\rho = -0.557$, $p = 9.83e-06$ | $\rho = -0.454$, $p = 0.00030$ | $\rho = -0.617$, $p = 2.04e-08$ | $\rho = -0.524$, $p = 4.56e-06$ |
| **Total DWT** | $\rho = -0.611$, $p = 0.000213$ | $\rho = -0.241$, $p = 0.144560$ | $\rho = -0.785$, $p < 2e-16$ | $\rho = -0.729$, $p < 2e-16$ | $\rho = -0.820$, $p < 2e-16$ | $\rho = -0.783$, $p < 2e-16$ |
| **Clustering coefficient** | $\rho = 0.346$, $p = 0.048716$ | $\rho = -0.039$, $p = 0.815880$ | $\rho = 0.654$, $p = 5.98e-08$ | $\rho = 0.548$, $p = 7.20e-06$ | $\rho = 0.556$, $p = 8.50e-07$ | $\rho = 0.437$, $p = 0.000197$ |

Finally, as Table 12 shows, the highest Spearman's correlation coefficients were recorded in 2010 and 2020. This suggests that the 2008 financial crisis and the subsequent Covid-19 pandemic led to a more defined hierarchy in traffic flows. This situation is likely to have been caused by the need for shipping companies to have their routes rationalised more effectively. This situation therefore suggests that, in response to a crisis, carriers tend to concentrate traffic flows more heavily on their hub ports, at the expense of a more widespread distribution of services. In the short term, this may penalize smaller ports, which risk losing direct traffic and becoming increasingly dependent on hub ports. However, as shown in Figure 45, the analysis of the Italian ego-network also indicates that in 2010 and, subsequently, in 2023 the targeted attack curve appears to shift further to the right, suggesting an increase in the resilience of maritime networks following these shocks.

## 3.6 Conclusions

This study provides valuable insights into the evolving role of Italian ports within the Mediterranean maritime network. The development of major hub ports in the Mediterranean appears to have reduced the centrality of Italian gateway ports within the global maritime network to some extent. The increasing hierarchical structure of Mediterranean maritime networks, particularly evident in the emergence of major hubs around the ports of Algeciras, Tangier Med and Valencia in the western Mediterranean, and around the port of Piraeus in the eastern Mediterranean, has concentrated key intermediary functions in a limited number of ports. In this context, several Italian ports have lower network centrality values, particularly for measures such as closeness and eigenvector centrality. This suggests that parts of the Italian port system are gradually becoming peripheralised within global liner shipping networks.

At the same time, analysis of hub dependency reveals significant disparities among Italian ports. Those capable of generating larger traffic volumes, particularly in terms of TEU throughput and DWT, tend to exhibit lower levels of hub dependency, indicating greater autonomy within international liner service networks. Conversely, smaller ports exhibit higher levels of hub dependency, relying on indirect connections via Mediterranean hubs. However, some ports deviate from this general relationship. Notably, Civitavecchia and Ravenna show patterns in the most recent years of the analysis that do not fully conform to the overall trend, suggesting specific functional roles or regional service dynamics within the Italian port system.

When examining vulnerability, however, the relationship with hub dependency appears less clear. The ego-network analysis suggests that the Italian maritime network has become more resilient over time, as evidenced by the slower fragmentation of the giant component in recent years. At the same time, the degree of regionalization of maritime networks, partly influenced by geographical conditions, such as those observed in Adriatic ports, appears to affect network density and, consequently, the potential resilience of ports that may also exhibit higher levels of hub dependency.

Finally, the lower vulnerability observed in both the global and Italian networks in 2023 may suggest that maritime networks have become more robust following the COVID-19 crisis. However, this remains a tentative observation and would require analysis over a longer post-crisis time period in order to be more reliably assessed.

# 4. Chapter 3: Uneven Maritime Connectivity, a Country-Level analysis of the Global Liner Shipping Network and the Hormuz crisis impact.

## 4.1 Introduction

This chapter addresses a third form of vulnerability in the maritime transport system, a form of vulnerability due to the unequal integration of countries into the global maritime network of liner services provided by container shipping companies. The well-known UNCTAD statement, cited in a large share of the literature on maritime transport, reminds us that approximately 80% of goods traded on the global market are transported, at least in part, by sea. Access to maritime transport, however, is far from being equally distributed across countries. As already emphasized in the previous chapter, the global port maritime network is strongly hierarchical (Ducruet and Notteboom, 2012), meaning that a small number of ports are highly connected to the rest of the world's ports, whereas the majority occupy more peripheral positions and are, to varying degrees, dependent on central hubs.

As several scholars observes, maritime transport costs are shaped by a combination of factors, including port efficiency, logistics infrastructure, port connectivity, and distance from other connected ports. Over time, however, the latter factor appears to have become increasingly marginal (Wilmsmeier and Hoffmann, 2008). By contrast, the quality of infrastructure (Martínez-Zarzoso et al., 2003) and port inefficiency have been shown to translate into an indirect "tariff" that affects final transport costs (Sanchez et al., 2003; Clark et al., 2004). Nevertheless, port connectivity has increasingly emerged as one of the most decisive determinants of transport costs. Wilmsmeier et al. (2006) and Wilmsmeier and Martínez-Zarzoso (2010) demonstrate that a port's peripheral position within the global maritime service network has a greater impact than physical distance per se, and that route centrality significantly influences transport costs. This impact is even stronger in the case of routes linking two peripheral countries, given the hierarchical structure of the network.

A number of studies have also shown that the connectivity of a port or a country is a significant factor shaping trade flows between countries (Lun and Hoffmann, 2016; Fugazza and Hoffmann, 2017; Hoffmann et al., 2020). As also noted in the previous chapter, many studies examine the connectivity of a port and its position within the global maritime network through centrality measures derived from complex network analysis (Ducruet, 2020), based either on vessel movements or on liner shipping services. Other studies have developed composite indices with multiple components to measure the connectivity of ports and countries, such as the indices produced by UNCTAD like the Liner Shipping Connectivity Index (LSCI) (Hoffmann, 2005), the Port Liner Shipping Connectivity Index (PLSCI) (UNCTAD), and the Liner Shipping Bilateral Connectivity Index (LSBCI) (Fugazza and Hoffmann, 2017) or the Container Port Connectivity Index (CPCI) (Bertholdi et al., 2016). These indices incorporate measures related to the number of direct connections of a port or country, the number of transhipments required to connect to other countries (in the case of the LSBCI), as well as the number of maritime services serving a port, weekly service frequency, vessel size, and the number of shipping companies operating liner services on different routes. Several studies have shown that the need for transhipment between two countries is correlated with a reduction in trade (Fugazza and Hoffmann, 2017; Saeed et al., 2021). The level of competition has also been shown to affect both trade (Hummels et al., 2009) and transport costs (Wilmsmeier and Hoffmann, 2008), as high market concentration negatively influences both dimensions.

This chapter examines some of these aspects of country connectivity by focusing on two main factors. The first is the degree of countries' peripherality within the global maritime network; the second is the degree of countries' dependence on the number of the shipping companies for their maritime connections, that could be observed by the number of liner companies that provide maritime services.

Both factors can be interpreted as sources of vulnerability. A poorly connected and more peripheral country tends to have fewer alternative connections, thereby lacking the redundancy needed to absorb network shocks. Likewise, strong market concentration increases vulnerability to the commercial strategies of liner shipping companies and to service restructurings triggered by exogenous shocks (Grzelakowski, 2023; European Commission, 2023). The work presented in this chapter therefore offers a global-scale analysis of these two dimensions and seeks to address several key research questions: First, how are countries hierarchically positioned within the global liner shipping service network? Second, which countries display the highest levels of maritime peripherality and dependence on a limited number of carriers? Third, how do different service structures,namely, interoceanic, extra-regional and regional, shape national vulnerability? Finally, does a disruption scenario, as that currently affecting the Strait of Hormuz, confirm or challenge the vulnerability hierarchy identified through the analysis?

To answer these questions, all liner services operated by the top 30 container shipping companies were analysed. Together, these companies currently account for approximately 94% of the global fleet's carrying capacity (Alphaliner, 2026). Based on these services, the global container maritime network was reconstructed and for each country were calculated the number of services, the number of companies operating those services and the total annual cargo capacity of the country. All services were classified as regional, extra-regional, and intercontinental in order to capture countries' different structure of services within the maritime global network. Furthermore, to calculate the degree of peripherality within the network, the minimum number of transhipments required for a country to connect to all the others was determined. A Principal Component Analysis (PCA) was carried out to classify the countries, and based on the extracted components, the dataset was clustered into seven clusters using k-means clustering. Finally, the short-term impact on the global maritime network of a blockade of the Strait of Hormuz was analysed, examining the effect on global transhipment distances and on services provided by the Persian Gulf countries under two scenarios involving the exclusion of ports affected by the crisis. This analysis was carried out to attempt to link clustering to a real-world case of disruption not directly linked to the measures under consideration.

The chapter is divided into six sections. The first provides a brief literature review on maritime connectivity and its effects on transport costs and trade, competition, and the maritime networks of container carriers, as well as port regions. The second presents the data and methodology employed. The third analyses the components extracted by PCA and the definition of the clusters. The fourth section analyses the results of the clustering. The fifth section analyses the impact of the blockade of the Strait of Hormuz on the global maritime network in relation to clustering. Finally, the sixth section sets out the conclusions.

## 4.2 Literature review

Maritime connectivity is widely recognised as a key factor in transport costs and, consequently, in countries' trade performance. One strand of literature focuses on the relationship between connectivity and maritime transport costs, reconsidering the role of geography in shaping freight rates. Early studies traditionally assumed that distance was one of the main determinants of transport costs, and therefore of trade competitiveness. However, subsequent research has shown that geography matters not only in terms of physical distance, but also in terms of the relative position of ports and countries within maritime transport networks. For example, Martínez-Zarzoso et al. (2003) find that transport costs increase with not only distance, but also weaker infrastructure quality and the use of less efficient ports of departure. This suggests that the geography of transport is mediated by infrastructural and operational conditions.

Similarly, Wilmsmeier et al. (2006) found that port efficiency, port infrastructure, private sector participation and, in particular, inter-port connectivity significantly reduced international maritime transport costs in their study of trade flows among 16 Latin American countries. They found that a greater frequency of direct liner services lowered freight rates, indicating that the spatial organisation of maritime services, rather than merely the linear separation between origin and destination, plays a decisive role in transport pricing. They also demonstrate that freight rates are not proportional to distance, as doubling the distance results in a much smaller increase in transport costs. This implies that maritime geography is filtered through network organisation, economies of scale, and service structure.

Wilmsmeier and Hoffmann (2008) further develop this argument by analysing intra-Caribbean freight rates. They show that variables relating to liner shipping connectivity, such as the number of direct services and carriers operating between two countries and the absence of transhipment requirements, explain freight rates more effectively than distance alone. Geographically, their findings suggest that not only does the distance between two places matter, but also whether they are directly linked, how many operators serve the route and whether they are situated along dense or marginal shipping corridors. They demonstrate that transhipment incurs substantial additional costs, equivalent to the geographical separation of countries being significantly increased, thus reinforcing the idea that network discontinuities can create forms of 'effective distance' that are more significant than physical mileage. Wilmsmeier and Martínez-Zarzoso (2010) further advance this relational understanding of geography by explicitly comparing geographical distance with the structure of the liner service network. Their analysis demonstrates that the configuration of the maritime service network explains a greater proportion of the variance in transport costs than distance alone. This leads them to formulate the notion of the 'cost of peripherality': countries located in peripheral positions within the global liner shipping network face higher freight rates, particularly when trading with other peripheral countries. From this perspective, geography is topological as well as territorial, since disadvantages arise from poor network embedding, remoteness from main hubs and weak connection to central maritime routes. Similar conclusions emerge from Wilmsmeier and Perez (2005) that stressed that maritime service supply and fleet deployment structures shape the economic consequences of geographical location by reducing or amplifying the costs associated with remoteness.

A second strand of literature shifts the focus from freight rates to the broader trade effects of maritime connectivity. Once again, it is emphasised that geography affects trade through network position as much as through absolute distance.

A significant contribution in this regard is the Liner Shipping Connectivity Index (LSCI) developed by Hoffmann (2005), which was subsequently adopted and regularly published by UNCTAD. This index measures countries' integration into global liner shipping networks. The LSCI was subsequently extended to the bilateral dimension by Fugazza et al. (2013) to create the Liner Shipping Bilateral Connectivity Index (LSBCI), which was further elaborated by Fugazza and Hoffmann (2017). By incorporating the number of transhipments, common direct connections, the degree of competition on connecting services and vessel size, the LSBCI recognises that bilateral accessibility depends on the relational geography of country pairs within the global network. In other words, two countries may be relatively well connected despite being geographically distant if they are integrated into major trunk routes, while countries that are closer together may remain poorly connected if they occupy peripheral or fragmented positions in the network.

Empirical findings from Fugazza and Hoffmann (2017) show that each additional transhipment significantly reduces bilateral exports. In contrast, stronger trade flows are associated with more common direct connections, greater competition and larger vessel capacity. These results highlight that trade is penalised not only by remoteness in the conventional sense, but also by network-induced remoteness, namely, the need to pass through intermediate hubs or indirect service chains.

Hoffmann et al. (2020) demonstrate the same logic, showing that South Africa’s bilateral trade is positively influenced by common direct connections and competition among carriers, while transhipments and direct and sailing distance have negative effects. Their distinction between direct and maritime distance is particularly relevant, as it emphasises that the actual geography of shipping does not correspond to straight-line distance, but rather to the routes made possible by the structure of maritime services.

Similarly, Lun and Hoffmann (2016), focusing on ASEAN, demonstrate that stronger liner shipping connectivity supports both intra-regional and extra-regional trade. This suggests that integration into dense shipping networks can also improve a region's external trade performance. Overall, this body of literature indicates that maritime transport costs and bilateral trade flows depend less on physical distance than on the spatial and relational organisation of liner shipping services, the degree of direct connectivity, the intensity of competition and the relative centrality or peripherality of countries within global maritime networks.

### 4.2.1. Carrier Strategies and Market Concentration as Sources of Vulnerability in Container Shipping

A substantial body of literature has examined how container carriers organise their service networks strategically and the ways in which these strategies shape the geography of maritime connectivity. In his analysis of Maersk's global maritime network, Frémont (2007) shows that direct multi-port services and hub-and-spoke configurations are structurally complementary, rather than alternative, models. Global carriers can extend their coverage to secondary and regional markets while maintaining flexibility and operational efficiency by combining mainline east–west and north–south services with strategically located transhipment hubs.

This is consistent with the findings of Ferrari et al. (2008), who demonstrate that alliances and cooperative agreements enable shipping lines to expand their service coverage, exploit economies of network and scope, and concentrate capacity in strategically located markets, which are often linked to home-market advantages.

More broadly, Ducruet and Notteboom (2012) argue that the design of liner services relies on a variety of configurations, including line bundling, pendulum services, interlining, relay operations and hub-and-spoke systems. Through these configurations, carriers balance the demand for frequency and accessibility with the need for cost efficiency and vessel utilisation.

Recent work has further emphasised the role of alliances in restructuring the global shipping network. Gou et al. (2024) demonstrate that alliances primarily emerge among the strongest competitors, transforming competition into coordinated cooperation through the sharing of vessels, routes and schedules. From this perspective, alliance-based overlay improves connectivity, density, and network stability, although these benefits are unevenly distributed among carriers and regions. The geographical dimension of these processes is important because different alliances develop distinct spatial cores and complementary regional orientations.

At the port level, Liu et al. (2022) demonstrate that port centrality is highly network-specific; while major European ports retain dominant hub positions in the China–Europe network, their relative importance is more differentiated in intra-European services. Similarly, Yap and Zahraei (2018) demonstrate that restructuring alliances on the Asia–Europe route resulted in significant service rationalisation across Southeast Asian transhipment hubs. This reduced the number of calls and increased the reliance of ports such as Port Klang and Tanjung Pelepas on alliance-level strategies.

Yap et al. (2023) build on this by demonstrating that shipping connectivity and market contestability must be analysed not only at the aggregate port level, but also at the level of individual trade routes, where alliance dominance tends to be more evident.

Overall, this body of work indicates that carriers and alliances are instrumental in shaping the spatial structure of global maritime networks, thereby determining which ports and regions benefit from direct connectivity, a dense service supply and strategic integration into major shipping corridors.

A second strand of literature focuses more explicitly on the implications of these developments for market concentration, freight rates and the position of shippers.

Hummels et al. (2009) make a key contribution to this area of research by showing that shipping costs are not solely driven by distance, but are also influenced by product characteristics and the market power of carriers. They found that concentrated shipping markets lead to higher freight rates and reduced trade, particularly adversely affecting developing and non-OECD countries, which tend to have fewer competing carriers and higher ad valorem transport costs. Thus, market concentration becomes a mechanism through which unequal trade conditions are perpetuated. The issue became even more apparent during the Covid-19 crisis.

Grzelakowski (2023) argues that the pandemic exacerbated existing tendencies towards concentration, horizontal consolidation and vertical integration within the container shipping industry. This strengthened the market power of a small group of dominant operators. This enabled exceptional pricing strategies that imposed significant costs on shippers, freight forwarders and global supply chains.

The European Commission (2023) reached a similar conclusion in its evaluation of the Consortia Block Exemption Regulation, finding that the extraordinary market conditions of 2020–2023 were characterised not only by sharp freight-rate increases, but also by deteriorating service quality, reduced direct connectivity and lower schedule reliability. The evaluation challenges the earlier assumption that consortia necessarily generate consumer benefits, showing instead that exempted cooperation increasingly reinforced the position of the largest carriers rather than promoting effective competition. Within this framework, it is the shippers who are most directly exposed to the consequences of concentration. They face higher freight volatility, lower service reliability and reduced capacity to respond to carrier-led network reconfigurations during periods of crisis.

Overall, this body of literature suggests that market concentration in liner shipping has effects that extend far beyond the formation of prices alone. It also reshapes bargaining power, network access and the broader distribution of vulnerabilities across countries, ports and supply chain participants.

### 4.2.2. Network analysis measures of connectivity, geography of maritime networks and ports.

A substantial body of literature has examined maritime connectivity as a key dimension through which the geography of shipping networks and port hierarchies can be understood. Rather than considering ports as merely fixed locations within global trade, these studies analyse how their position within maritime networks influences accessibility, centrality and competitive advantage.

One strand of research takes a long-term view of the evolution of global maritime connectivity. Using Lloyd's Shipping Index data for the period 1890–2000, Kosowska-Stamirowska et al. (2016) demonstrate that the global maritime trade network expanded considerably in terms of the number of active ports, while also becoming more navigable and increasingly structured according to hub-and-spoke logics. They conclude that the historical evolution of maritime connectivity involved not only network expansion, but also structural optimisation to enhance circulation well before the introduction of containers.

Ducruet et al. (2018) offer a related historical perspective, analysing maritime networks as systems of cities and showing that the relationship between traffic volume, urban size, and maritime centrality has weakened over time. The study also reveals a significant geographical shift in maritime connectivity, with a move from the North Atlantic to the Asia-Pacific region, reflecting the relocation of strategic hubs and trade flows within the global economy.

A second strand of literature focuses more specifically on port connectivity and hierarchical differentiation within liner shipping networks. Jiang et al. (2015) analysed global liner services, focusing on the Asia-Pacific region, and demonstrated that port competitiveness depends heavily on the ability to function efficiently as a transhipment node within the broader network. Their findings highlight the importance of regular liner services and network accessibility in explaining why ports such as Singapore, Busan, Qingdao and Shanghai are in leading positions.

Wang and Cullinane (2016) further develop this perspective by proposing a multidimensional framework for port centrality based on degree, closeness and betweenness in directed, weighted shipping networks. They demonstrate that connectivity is not a single attribute since direct connections, accessibility to the wider network and intermediary transhipment functions capture different dimensions of a port's position.

Similar conclusions emerge from Ducruet et al. (2010b), who argue that centrality and hub dependence must be considered together to understand port vulnerability. In Northeast Asia, they demonstrate that ports with numerous connections may still be heavily dependent on dominant hubs, and that high traffic volumes do not necessarily equate to strong network autonomy.

Similarly, Ducruet et al. (2010c) found that rising connectivity did not eliminate concentration around a limited number of major hubs in their study of the Atlantic network, but instead reconfigured regional hierarchies through new forms of inter-port dependence. Overall, these studies suggest that maritime connectivity is deeply uneven and that the benefits of network integration are distributed hierarchically across ports.

A third strand of literature examines how recent disruptions, carrier strategies and geopolitical change have reshaped maritime connectivity. Using AIS-based freight-flow data, Li et al. (2024) demonstrate that the effects of the Covid-19 crisis on global container shipping connectivity were highly uneven: the strongest disruptions affected major interregional corridors and hub ports linking East Asia, Europe, and North America, whereas several peripheral and feeder connections proved relatively more resilient. Their analysis suggests that the crisis exposed the spatial asymmetry of connectivity patterns without fundamentally dismantling the structure of the global network. Recent work has also demonstrated that connectivity depends on the differentiated strategies employed by shipping lines.

Pan et al. (2025) modelled the global liner shipping system as a multiplex network, in which each carrier forms a distinct layer. They demonstrated that aggregate connectivity emerges from the combination of heterogeneous, carrier-specific routing strategies. Major carriers dominate the backbone of global connectivity, while smaller operators tend to act as regional specialists or feeders.

Tagawa and Meng (2025), focusing on the evolution of major trade routes, show that route-specific connectivity patterns are shaped by the enduring advantages of dominant ports such as Singapore and Busan, as well as the growing influence of major shipping lines.

Finally, Saeed et al. (2021) examine how the Belt and Road Initiative could reconfigure maritime connectivity, reducing the number of transhipments required between countries and improving the directness and efficiency of shipping connections. This would strengthen bilateral trade flows.

Overall, this body of literature demonstrates that maritime connectivity is not merely a technical feature of transport systems, but rather a dynamic and unevenly distributed resource influenced by network structure, port hierarchy, carrier strategies and broader geopolitical shifts.

### 4.2.3. Port Communities, Maritime Regions, and the Uneven Geography of Global Connectivity

An increasing amount of research has examined the global geography of port communities and maritime regions. This research has shown that maritime networks are not only structured by the hierarchy of individual ports, but also by the formation of regionally and functionally coherent port systems.

Ducruet and Notteboom (2012) make a significant contribution to this field by demonstrating that the global container shipping network is shaped by a combination of strong intra-regional clustering and selective inter-regional connections. Their analysis reveals that the majority of traffic is concentrated within the major regional hubs of Asia, Europe and North America, whereas long-distance connections play a more selective role in structuring global circulation.

Ducruet and Zaidi (2012) further develop this regional perspective by identifying 'maritime constellations' within the global liner shipping network. They demonstrate that port communities are often organised around geographical proximity, coastal continuity and regional clustering. However, these spatial logics are partly reworked by long-distance functional ties, historical relationships and the strategic role of bridge ports.

Similarly, Jarumaneeroj et al. (2023) analyse the evolution of the global container shipping network through the combined lenses of port connectivity and trading community structure. They argue that community formation is shaped less by simple geographical contiguity than by broader trade patterns and changing network configurations. They find that major events such as the Panama Canal expansion and the bankruptcy of Hanjin Shipping influenced not only connectivity rankings, but also the composition and reorganisation of trading communities.

Several studies also emphasise that the geography of maritime regions is deeply unequal and cannot be understood adequately through traffic volume alone. In one of the few explicitly inter-regional analyses of the global shipping network, Xu et al. (2015) show that East Asia, Northwest Europe and the Europe-Mediterranean region occupied the most prominent positions consistently between 2001 and 2012, whereas East and North Africa remained peripheral.

Notably, their findings suggest that increased traffic does not invariably lead to an improvement in a region's network position. For instance, East Asia's status as a dominant trade hub does not correspond with equivalent intermediary centrality. This suggests that regional maritime power depends on multiple dimensions, including connectivity, intermediary centrality, dominance and vulnerability. Notteboom (2006) also addresses the issue of inequality, revisiting traffic concentration in seaport systems and demonstrating that port inequality varies significantly across maritime regions, reflecting different patterns of structural integration into liner shipping networks.

Bartholdi et al. (2016) in the paper on CPCI provided a more nuanced understanding of the aggregation and distribution functions of ports within global and regional systems.

This perspective is also relevant to more recent regional analyses. For example, Liu et al. (2024) examined the Regional Comprehensive Economic Partnership (RCEP) shipping network and found that regional shipping systems can display distinct structural properties and resilience patterns compared with the global network as a whole. Guerrero and Rodrigue (2014), finally, situate these changes within the broader context of containerisation, demonstrating that the geography of global port development has gradually shifted from traditional triad economies to East and Southeast Asia. Selected transhipment hubs have gained prominence through successive cycles of adoption, expansion, and restructuring.

Overall, this body of work demonstrates that the geography of port communities and maritime regions is dynamic, uneven and relational. Ports are not only embedded in local and national settings, but also in wider regional clusters and global community structures, which are shaped by trade patterns, carrier strategies, technological change and shifting inter-regional hierarchies.

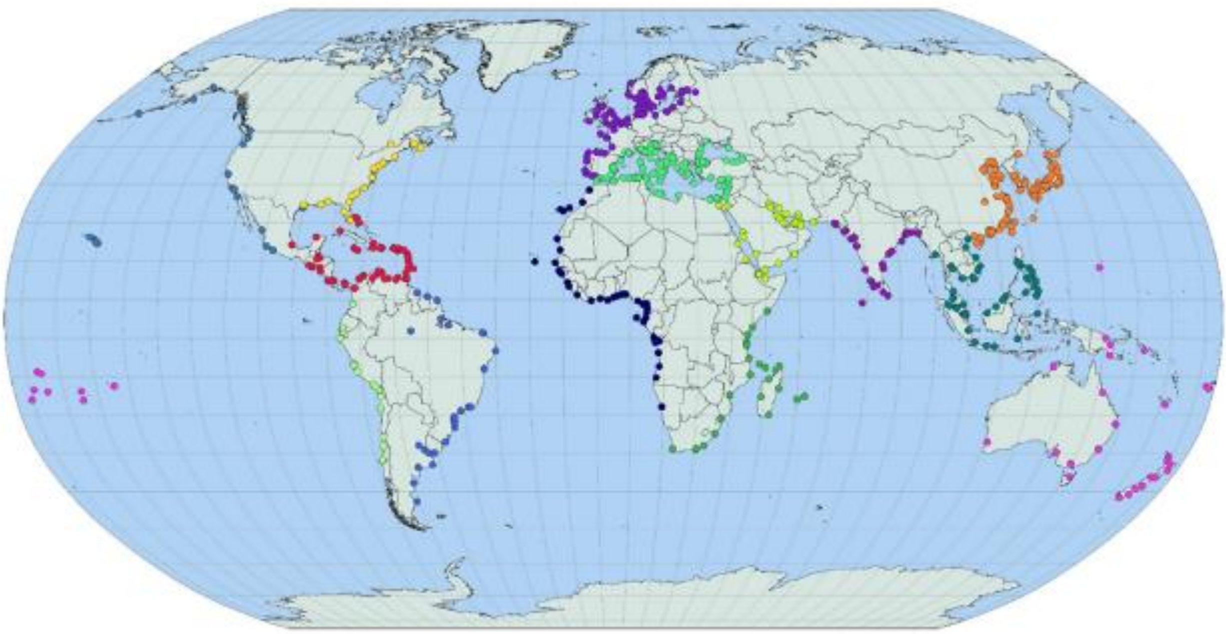
## 4.3 Data and methodology

### 4.3.1. Data and variables

This chapter reconstructs an analysis of the global liner shipping service network at the country level analysing the service rotations of the top 30 container shipping companies worldwide by carrying capacity (TEU), deployed at the ed of February 2026. These carriers account for around 94% of the global container ship fleet's cargo capacity (Alphaliner, 2026). Information on rotations and services has been sourced from the shipping companies' official websites and supplemented by using the databases on the EcomDB.com website. The ports listed in the declared rotations of these carriers are used as network nodes in a Space-P structure where all ports in the same service are considered as directly connected. Each port is assigned an ISO 3166-1 alpha-3 country code. ISO 3166-1 alpha-3 codes are three-letter country codes used to represent countries, dependent territories, and special areas of geographical interest. They are defined in ISO 3166-1, which forms part of the ISO 3166 standard published by the International Organization for Standardization (ISO). This allows the aggregation of service and network indicators at the country level.

Country-level connectivity and peripherality within the service network were first examined by reconstructing a port-based network from service rotations and then calculating the minimum topological distance between each country and the rest of the network through an ego-network centred on the ports of the country concerned. This approach made it possible to identify the minimum number of transhipments required to reach, from any port of a given country, the first accessible port in every other country. On this basis, the number of countries reachable at topological distance 1 (direct connections), distance 2 (one transhipment), and up to distance 5 (four transhipments), which represented the maximum observed network distance, was calculated. All the ports of the network are grouped by country and the topological distance from one country to the others has been calculated using the minimum path length between all the ports of a country and the other ports of the network. The lowest value of the minimum path lengths from a port of the Country A to a port of a Country B is considered as the minimum transhipment distance. This measure has been calculated for all the countries in the network.

*Figure 48 Port of the global liner service network divided in regions defined by the author*



In addition, the main characteristics of each country's maritime services were measured. First, the total number of services including at least one port of the country in their rotation was computed. Second, the number of operators providing one vessel in at least one service calling at the country was identified. Thirdly, the country's annual transport capacity is calculated by converting the weekly capacity and multiplying it by the number of weeks in 2026. Where a service called at more than one port within the same country, this capacity was multiplied by the number of the ports of the country in the service rotation and then aggregated across all services serving the country.

A key difference between this measure and the indicators used in UNCTAD's Liner Shipping Connectivity Index (LSCI) is that, in this analysis, services were further classified into three macro-categories according to the geographical scope of the routes served.

Given the hierarchical nature of the maritime network, in which long-distance interoceanic routes form the backbone of the global service system, distinguishing among service types makes it possible to capture more accurately the degree of a country's integration into the global network.

Accordingly, services were classified as interoceanic, extra-regional, or regional. Interoceanic services were defined as those linking ports across an ocean basin; extra-regional services as those connecting ports belonging to different but geographically proximate port regions; and regional services as those connecting only ports within the same port region.  An exception as been made for intra-asiatic services that are commonly considered as regional services. For each of these three categories, the number of services, number of operators, and annual carrying capacity were also calculated. The ports regions have been classified as shown in the Figure 48 and the services classification is shown in Table 14.

These measures, summarized in Table 13, were therefore included as country-level variables in our analysis. The first twelve can be interpreted as describing the structure of a country's connectivity, capturing its scale in terms of services and carrying capacity, the breadth of its network across different service types, and the degree to which it may depend on a limited number of operators. The last four variables, instead, capture the country's level of peripherality within the global network in terms of transshipment.

*Table 13 Variables of the service structure and transhipment distance*

| Variables |
|---|
| **N° of operators - Interocean** |
| **N° of services - Interocean** |
| **Annual cargo capacity - Interocean** |
| **N° of operators - Extra regional** |
| **N° of services - Extra regional** |
| **Annual cargo capacity - Extra regional** |
| **N° of operators - Regional** |
| **N° of services - Regional** |
| **Annual cargo capacity - Regional** |
| **N° of country directly connected** |
| **N° of country 1 transhipment** |
| **N° of country 2 transhipment** |
| **N° of country more than 3 transhipment** |

In order to control multicollinearity in the regression model and to better identify and separate the effects of shipping connectivity and port infrastructure, we use PCA to calculate non-collinear variables from the set of variables described above.

In order to identify broader patterns of similarity, the national-level indicators are then used in a cluster analysis employing the k-means clustering algorithm. The data was clustered using standardised measures in order to obtain a more consistent result that is less influenced by the different value scales. In order to interpret the characteristics of the different clusters, the mean of the values for each cluster was calculated for each measure, and the difference between these means and the mean value of the measure in the dataset was calculated. This analysis has identified ten groups of countries for which the interpretation is clearer.

*Table 14 Services classification*

| Regional | Extra-regional | Interoceanic |
|---|---|---|
| Bay of Bengal services | Far East / Indian subcontinent | Americas / Middle East or South Asia |
| Intra Asia services - Indonesia domestic | North Europe / Mediterranean | Americas and Africa / Oceania |
| Intra Asia services - NE Asia | Services Europe / Canary Islands and Morocco | Asia / North America and Canada |
| Intra Asia services - NE Asia-SE Asia | Services Europe / West Africa | Asia / North America services with Mexico calls |
| Intra Mediterranean | Services Middle East and South Asia / South and East Africa | Asia / North America services with USEC calls |
| Jones Act trades (USA) | US East Coast / East Coast of South America | Asia / North America services with USWC calls |
| Oceania - South Pacific Islands | US East Coast / West Coast of South America | Asia / Oceania |
| East Coast and West Coast of South America domestic services | US West Coast / South America | Europe / Caribbeans |
| Intra Asia services - China domestic | US East Coast / Caribbeans | Europe / East Coast of South America |
| Intra Asia services - SE Asia | Middle East and Indian subcontinent | Europe / Indian Ocean - Oceania - South East Asia |
| Local services South and East African | | Europe / Middle East or South Asia |
| North Europe only | | Europe / West Coast of South America |
| West Africa local feeders | | Far East / East Coast of South America and Caribbean |
| | | Far East / Middle East Gulf |
| | | Far East / Red Sea |
| | | Far East / West Coast South America |
| | | Med / Far East |
| | | Mediterranean / Caribbean / US West Coast |
| | | Mediterranean to USEC/ USWC |
| | | Mediterranean to USEC / Canada |
| | | North Europe / Far East |
| | | North Europe / US East Coast / Oceania |
| | | North Europe / West Coast South America |
| | | North Europe to US East Coast/ US West Coast |
| | | North Europe to USNH / Canada (St Lawrence) |
| | | Services Americas / South and East Africa |
| | | Services Americas / West Africa |
| | | Services Asia / West Africa |
| | | Services East Asia / South and East Africa |
| | | Services Europe / South and East Africa |

### 4.3.2. PCA components

Before performing the principal component analysis, N° of country 2 transhipment was excluded from the set of variables measuring the distribution of countries across distance classes. As these variables represent mutually exclusive shares, their sum is always equal to one for each observation. Retaining all categories would therefore lead to perfect multicollinearity and a singular correlation matrix, compromising the computation and interpretation of the principal components.

*Table 15 Eigenvalue, Explained variance, Cumulative explained variance of PCA component*

| Component | Eigenvalue | Explained variance | Cumulative explained variance |
|---|---|---|---|
| PC1 | 6,818553891 | 0,568212824 | 0,568212824 |
| PC2 | 1,966571568 | 0,163880964 | 0,732093788 |
| PC3 | 1,509435587 | 0,125786299 | 0,857880087 |
| PC4 | 0,598757822 | 0,049896485 | 0,907776572 |
| PC5 | 0,399322312 | 0,033276859 | 0,941053432 |
| PC6 | 0,292899497 | 0,024408291 | 0,965461723 |
| PC7 | 0,162752568 | 0,013562714 | 0,979024437 |
| PC8 | 0,099883773 | 0,008323648 | 0,987348085 |
| PC9 | 0,068872405 | 0,005739367 | 0,993087452 |
| PC10 | 0,048606831 | 0,004050569 | 0,997138021 |
| PC11 | 0,026102017 | 0,002175168 | 0,999313189 |
| PC12 | 0,00824173 | 0,000686811 | 1 |

Therefore, one variable was omitted to ensure the correlation matrix was full rank and to allow the PCA to be properly estimated. It was decided to retain the variable "No. of countries with more than 3 transhipments" in order to better capture the situation of extreme peripherality.

The correlation matrix and the Kaiser-Meyer-Olkin (KMO) test (0.730) proved to be significant, which indicates the sampling adequacy of the chosen variables. The PCA analysis was performed on standardised values from the original dataset. As can be seen in the Table 13, the PCA extracted three factors, explaining 85.78% of the intrinsic variance of the data fulfilling the Kaiser criterion with eigenvalues over 1.

**Components description**

Table 16 shows the values taken by the components for each different variable. The various components will be described and explained below.

*Table 16 Values of the variables for each component.*

| Variables/Component | PC1 | PC2 | PC3 |
|---|---|---|---|
| *N° of services - Interocean* | 0,351 | 0,151 | -0,016 |
| *N° of operators - Interocean* | 0,331 | -0,141 | -0,034 |
| *Annual cargo capacity - Interocean* | 0,314 | 0,283 | 0,029 |
| *N° of services - Extra regional* | 0,268 | -0,184 | -0,498 |
| *N° of operators - Extra regional* | 0,312 | -0,123 | -0,287 |
| *Annual cargo capacity - Extra regional* | 0,309 | 0,032 | -0,354 |
| *N° of services - Regional* | 0,311 | 0,302 | 0,285 |
| *N° of operators - Regional* | 0,256 | 0,099 | 0,393 |
| *Annual cargo capacity - Regional* | 0,291 | 0,361 | 0,242 |
| *N° of country directly connected* | 0,318 | -0,213 | -0,101 |
| *N° of country 1 transhipment* | 0,144 | -0,535 | 0,378 |
| *N° of country more than 3 transhipment* | -0,189 | 0,514 | -0,308 |

**PC1 - Strong direct connectivity and high global connectivity services structure**

PC1 identifies a dimension of strong direct connectivity and broadly developed maritime service provision. As can be seen in Table 16 the component is mainly associated with positive loadings for interoceanic services (0.351), interoceanic operators (0.331), directly connected countries (0.318), interoceanic annual cargo capacity (0.314), extra-regional operators (0.312), regional services (0.311), extra-regional annual cargo capacity (0.309), and regional annual cargo capacity (0.291).

This pattern indicates that high PC1 scores correspond to maritime systems characterised by a heterogenous service structure, diversified operator presence, and substantial cargo capacity across interoceanic, extra-regional, and regional scales.

The positive association with the number of directly connected countries (0.318) further suggests that this component captures a form of connectivity based on direct access rather than reliance on complex transhipment chains. Conversely, the negative loading for countries requiring more than three transhipments (−0.189) reinforces the interpretation of PC1 as a component of strong and efficient direct maritime integration. High scores for this component indicate countries that play a central role in the global and regional maritime network, with a wide range of services and operators. This suggests a highly resilient position and low dependence on a small number of operators.

**PC2 - Highly transhipment-related peripherality and regionally based services structure with limited number of operators.**

PC2 captures countries with an extreme peripheral position in the global maritime network with a regionally based service structure. As can be seen in Table 16 the component is most strongly associated with the number of countries requiring more than three transhipments (0.514) to connect themselves to all the others countries in the network. The values of the regional annual cargo capacity (0.361) and regional services (0.302) suggest that these countries are mainly regionally connected. The value of the N° of operators - Regional (0,099) suggest a globally limited number of operators.

At the same time, PC2 shows strong negative loadings for countries directly connected (- 0.213) and especially for countries requiring only one transhipment (- 0.535). This suggests that high PC2 scores describe a Country maritime network that remain connected through service and capacity provision, especially at the regional level, but are characterised by limited number of operators and a strong dependence on indirect, multi-stage transhipment connections. These countries appear to be extremely poorly connected and directly connected mostly to peripheral ports. This condition suggest a high vulnerability of the country's maritime system and a condition tendential dependence from a limited number of operators.

The value of the Annual cargo capacity - Interocean (0,283) is more difficult to interpret. It suggests that this component is also influenced by countries with inter-oceanic traffic. However, this information appears to be less relevant in the final clustering.

**PC3 - One transhipment peripherality and regionally based services structure with relatively high number of regional operators**

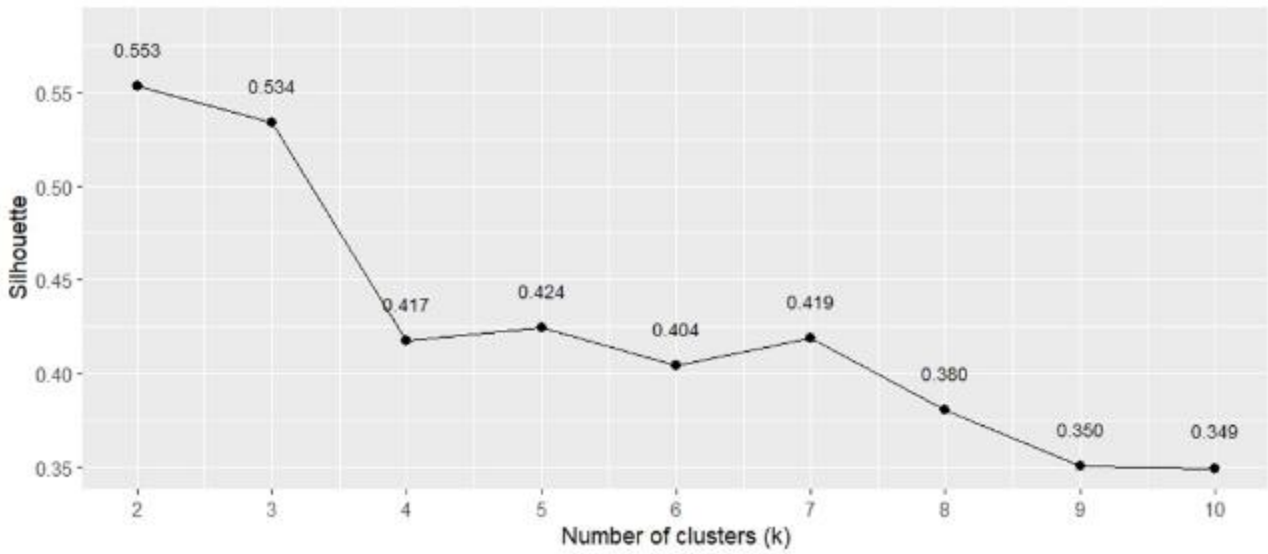
PC3 represents a semi-peripheral form of connectivity with the connection of most in the network require at least one transhipment, moreover, this component suggests a regionally oriented service structure with a relatively elevated number of operators. As can be seen in Table 16 the strongest positive loading is observed for regional operators (0.393), followed by countries requiring one transhipment (0.378), regional services (0.285), and regional annual cargo capacity (0.242).

In contrast, PC3 is negatively associated with extra-regional services (−0.498), extra-regional annual cargo capacity (−0.354), countries requiring more than three transhipments (−0.308), and extra-regional operators (−0.287). This loading structure indicates that high PC3 scores correspond to maritime systems that are relatively well embedded in regional networks and supported by a significant number of regional operators, but that remain weakly integrated into the global maritime network. High values for this component suggest a maritime connectivity structure that is directly connected to key ports in the global maritime network but is heavily reliant on regional hub ports connected by feeder services. This could therefore be interpreted as countries that are vulnerable due to their condition of hub dependency but a relatively resilient in terms of regional connections.

### **4.3.3.** K-mean clustering

For the selection of the number of the clusters to find in the k-means clustering it has been calculated the Average Silhouette Width (Batool and Hennig, 2021) for a different number of clusters. The average silhouette width (ASW) method is a commonly used diagnostic criterion for evaluating the quality of a clustering solution and for selecting the appropriate number of clusters.

*Figure 49 ASW value for clusters.*




For each observation, the silhouette value compares its average dissimilarity to observations within the same cluster with its average dissimilarity to observations in the nearest alternative cluster.

The resulting coefficient ranges from -1 to 1, where values close to 1 indicate that the observation is well matched to its assigned cluster and clearly separated from other clusters, values around 0 suggest that the observation lies between two clusters, and negative values indicate possible misclassification.

The ASW is obtained by averaging the silhouette values across all observations for a given number of clusters. In practice, the clustering solution with the highest ASW is considered the one that provides the best balance between within-cluster cohesion and between-cluster separation.

It's globally considered that a clustering with an average silhouette width of 0.7 is considered to be "strong", a value of 0.5 "reasonable", and a value of 0.25 "weak" (Rousseeuw, 1987). Figure 49 show the AWS value for the k-means clusters of the dataset.

To ensure both statistical rigor and substantive interpretability, clustering results are examined at multiple levels of granularity. The solution with a lower number of clusters (k = 3), supported by standard criteria such as the ASW, is adopted as the baseline representation of the main structure of the data. In addition, a finer partition (k = 7) is explored to capture additional heterogeneity and uncover substructures within the broader groups. Although the three-cluster solution was statistically more robust, the identification of China as a standalone cluster, a result also confirmed by the seven cluster solution, produced a relatively broad classification of the remaining countries. While this grouping offered a useful framework for understanding the general hierarchy of liner shipping services, a more disaggregated seven cluster solution was considered necessary in order to better capture and interpret the differences among countries. Furthermore, the division into seven clusters, whilst still yielding an acceptable silhouette score, proved to be more interpretable than a smaller number of clusters.

This dual approach allows for a robust identification of the core clustering patterns while providing a more detailed and nuanced interpretation of the data.

Cluster interpretation is conducted by combining information from the principal component space and the original variables. First, clusters are characterized by examining the mean values of the component scores within each cluster, which allows for identifying how clusters differ along the main latent dimensions extracted by the PCA. In addition, cluster profiles were analyzed using standardized variables in order to assess how each cluster deviates from the overall sample mean across the original indicators. This dual approach provides both a synthetic interpretation in terms of underlying dimensions and a more detailed understanding of the specific variables driving differences between clusters.

## 4.4 Results

### 4.4.1. 3 Clusters interpretation

*Figure 50 Maps of the K-means clusters (k = 3)*

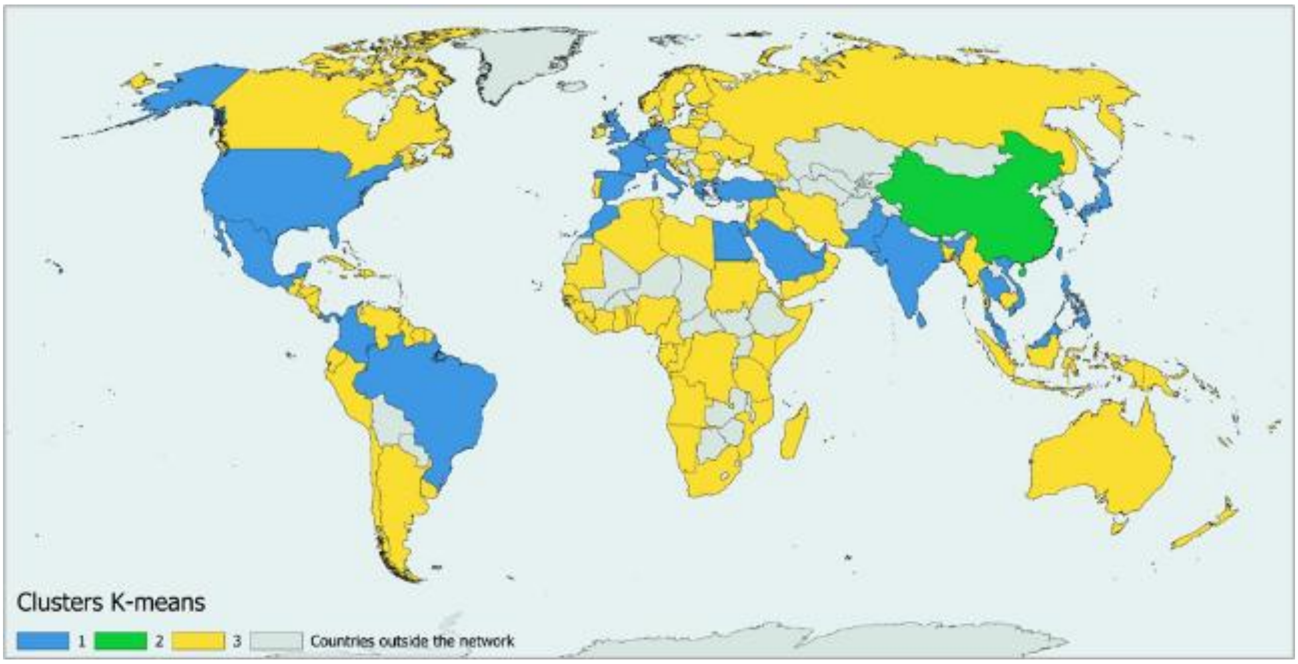



*Figure 51 3D graph distribution of the clusters*

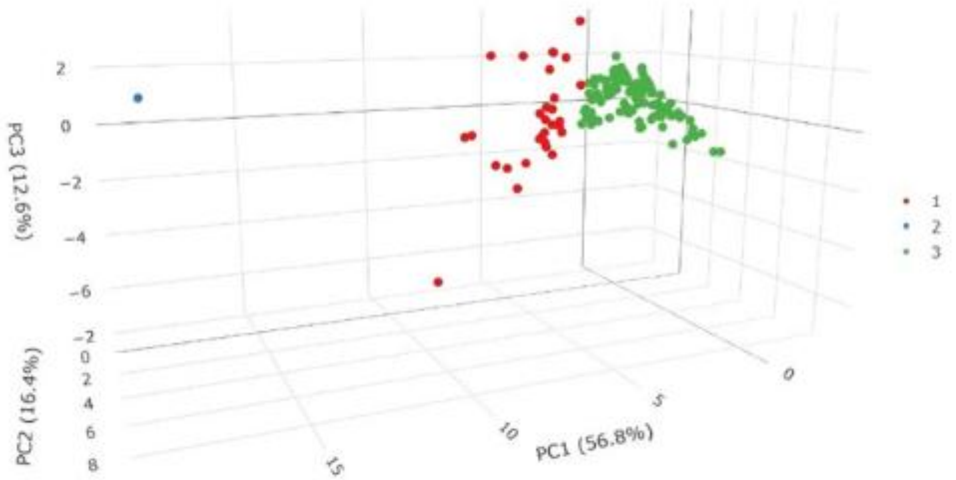


Figure 50 shows the division of the countries into three clusters. As shown in Figure 51 and Table 17, it is primarily PC1 that defines the division of these three clusters. It can be seen that Cluster 2, represented solely by China, has a significantly higher value than the others. As can also be seen from Table 4, this cluster has values significantly higher than the average across all service variables, values well above the average in terms of cargo capacity and the number of transoceanic and regional services. These high values in terms of the regional service network also explain the above-average values in PC2 and PC3. It also has a higher number of direct connections than the other clusters. This cluster has been categorised as a 'Highly serviced, central core Country'.

*Table 17 Mean of the scores of the component in the clusters (3 Clusters)*

| Clusters | PC1 | PC2 | PC3 |
|---|---|---|---|
| 1 | **3,509** | -0,590 | -0,485 |
| 2 | **19,112** | **9,202** | **2,084** |
| 3 | **-1,011** | 0,069 | 0,101 |

*Table 18 Cluster profiles: mean standardized values relative to the overall mean (3 Clusters)*

| Variables/Clusters | Cluster 1 | Cluster 2 | Cluster 3 |
|---|---|---|---|
| ***N° of services - Interocean*** | 1,138 | 7,949 | -0,342 |
| ***N° of operators - Interocean*** | 1,414 | 4,090 | -0,378 |
| ***Annual cargo capacity - Interocean*** | 0,625 | 10,716 | -0,239 |
| ***N° of services - Extra regional*** | 1,306 | 2,114 | -0,336 |
| ***N° of operators - Extra regional*** | 1,374 | 3,829 | -0,366 |
| ***Annual cargo capacity - Extra regional*** | 1,044 | 6,507 | -0,307 |
| ***N° of services - Regional*** | 0,808 | 9,000 | -0,270 |
| ***N° of operators - Regional*** | 1,075 | 3,697 | -0,292 |
| ***Annual cargo capacity - Regional*** | 0,490 | 10,810 | -0,208 |
| ***N° of country directly connected*** | 1,548 | 2,672 | -0,399 |
| ***N° of country 1 transhipment*** | 0,436 | -0,199 | -0,105 |
| ***N° of country more than 3 transhipment*** | -0,641 | -0,648 | 0,162 |

Cluster 1, on the other hand, shows a positive PC1. These countries tend to have a comprehensive global service structure and a medium-to-high annual capacity. Furthermore, they tend to have a above-average number of direct connections and reach a greater number of countries via a single transhipment than Cluster 2. This cluster has been defined as 'Well-served, globally connected countries'. As can be seen from Figure 50, most of these countries are geographically situated along the main global shipping routes: Europe–Far East, North America–Far East and Europe–North America. Furthermore, countries belonging to this cluster are located near most of the major global chokepoints, such as the Straits of Malacca, Gibraltar and the Bosporus/Dardanelles, as well as the Suez and Panama Canals.

Finally, Cluster 3 is found to have a negative PC1 value, indicating that these countries have below-average levels of services, operators and cargo capacity. They tend to have fewer inter-oceanic and extra-regional services. The positive values relative to PC2 and PC3 suggest that these countries are moving towards greater regional integration. However, the slight positivity of these values indicates that this group includes both peripheral and semi-peripheral countries in terms of their integration into the global maritime network. This group has been defined as comprising 'Medium low-serviced peripheral or semi-peripheral countries'.

## 4.4.2. 7 clusters

Figure 52 shows the results of the clustering analysis with seven clusters. As can be seen, there is a greater degree of heterogeneity compared to the 3-cluster analysis. China, which was classified in cluster 6 in the 3-

cluster division, remains a unique case and is in the same cluster here. Countries previously classified as 'well-served, globally connected' are now divided into three clusters: 4, 5 and 7. Cluster 3 of the previous classification, which was previously referred to as ‘Medium low-serviced peripheral or semi-peripheral countries’, is now divided into clusters 1, 2 and 3.

*Figure 52 Maps of the K-means clusters (k = 7)*

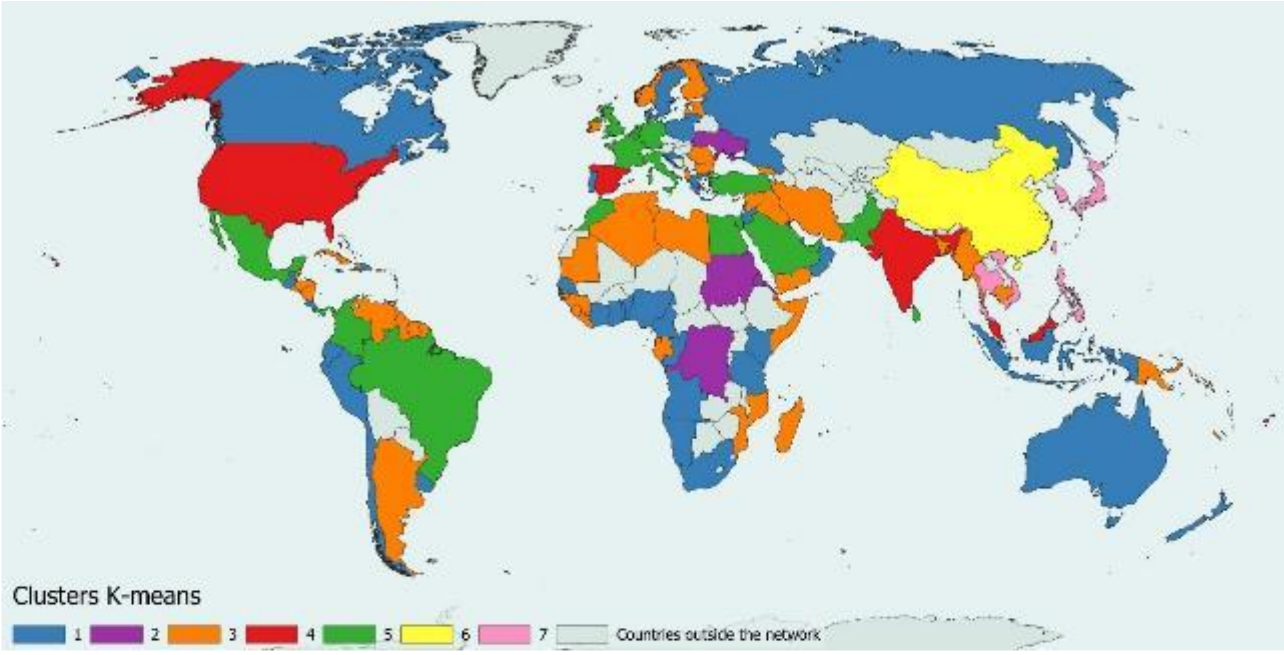



*Table 19 Mean of the scores of the component in the clusters (7 Clusters)*

| Cluster | PC1 | PC2 | PC3 |
|---|---|---|---|
| **1** | 0,081 | -0,968 | 0,504 |
| **2** | **-2,371** | **2,321** | **-1,166** |
| **3** | **-1,320** | 0,064 | 0,241 |
| **4** | **6,202** | -0,457 | **-2,637** |
| **5** | **2,751** | **-1,104** | **-1,084** |
| **6** | **19,112** | **9,202** | **2,084** |
| **7** | **3,737** | 0,594 | **2,315** |

The only country to change its classification ‘macrogroup’ compared with the 3-cluster analysis is Greece. This country is now classified within Cluster 1, which appears to be an intermediate group.

Indeed, as shown in Table 19, this cluster tends to be above average in relation to PC1, thus suggesting a reasonable provision of services and a lower degree of peripherality compared to the other two more peripheral clusters.

As shown in the Table 19 and Figure 52, with regard to PC1, for which high values indicate strong direct connectivity and a highly developed global service structure, a relatively clear hierarchy can be observed across the clusters. Cluster 6 records by far the highest values, followed by Cluster 4 with high values. Clusters 5 and 7 also display positive and relatively similar values, while Cluster 1 occupies an intermediate position. By contrast, Clusters 3 and 2 show low and extremely low values, respectively.

In terms of global service structure and integration into the maritime network, Cluster 6 can therefore be interpreted as the primary core of the global maritime network. Cluster 4 includes highly central and highly serviced countries. Clusters 5 and 7 comprise central countries with medium-high levels of international service provision. Cluster 1 represents an intermediate group, characterised by a smaller service scale and moderate integration into the global network. Finally, Clusters 3 and 2 correspond to peripheral and strongly peripheral countries, respectively, with low and extremely low levels of service provision.

*Figure 53 3D visualization of the cluster distribution related to the principal component.*

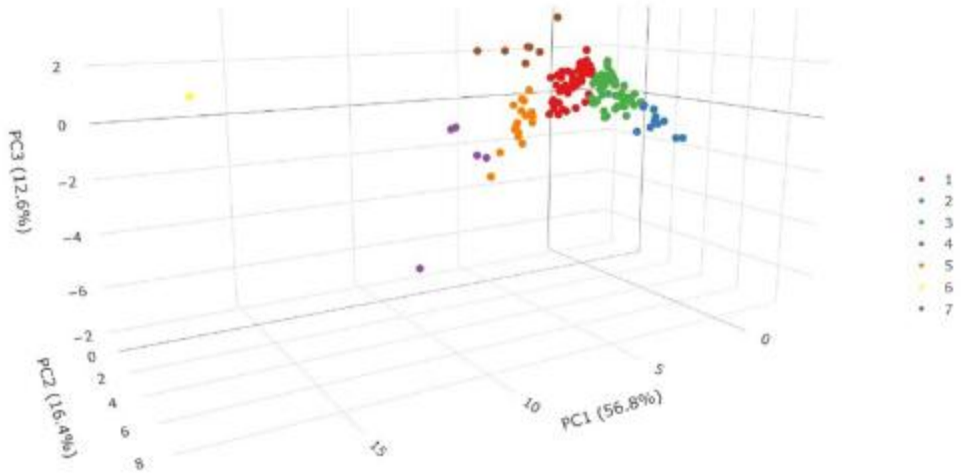



*Table 20 Cluster profiles: mean standardized values (z-scores) relative to the overall mean (7 Clusters)*

| Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| *N° of services - Interocean* | -0,142 | -0,464 | -0,444 | 2,509 | 0,842 | 7,949 | 1,052 |
| *N° of operators - Interocean* | 0,267 | -0,786 | -0,699 | 1,930 | 1,324 | 4,090 | 1,378 |
| *Annual cargo capacity - Interocean* | -0,149 | -0,291 | -0,287 | 1,652 | 0,439 | 10,716 | 0,447 |
| *N° of services - Extra regional* | -0,122 | -0,550 | -0,416 | 3,336 | 1,341 | 2,114 | -0,040 |
| *N° of operators - Extra regional* | -0,061 | -0,684 | -0,471 | 2,339 | 1,287 | 3,829 | 1,031 |
| *Annual cargo capacity - Extra regional* | -0,180 | -0,402 | -0,363 | 3,080 | 0,954 | 6,507 | -0,054 |
| *N° of services - Regional* | -0,162 | -0,373 | -0,301 | 0,975 | 0,124 | 9,000 | 2,382 |
| *N° of operators - Regional* | -0,031 | -0,644 | -0,344 | 1,082 | 0,320 | 3,697 | 2,909 |
| *Annual cargo capacity - Regional* | -0,147 | -0,260 | -0,228 | 0,583 | 0,027 | 10,810 | 1,597 |
| *N° of country directly connected* | 0,219 | -0,917 | -0,656 | 2,227 | 1,642 | 2,672 | 0,910 |
| *N° of country 1 transhipment* | 0,821 | -2,070 | -0,114 | 0,066 | 0,370 | -0,199 | 0,811 |
| *N° of country more than 3 transhipment* | -0,583 | 2,253 | -0,003 | -0,648 | -0,635 | -0,648 | -0,648 |

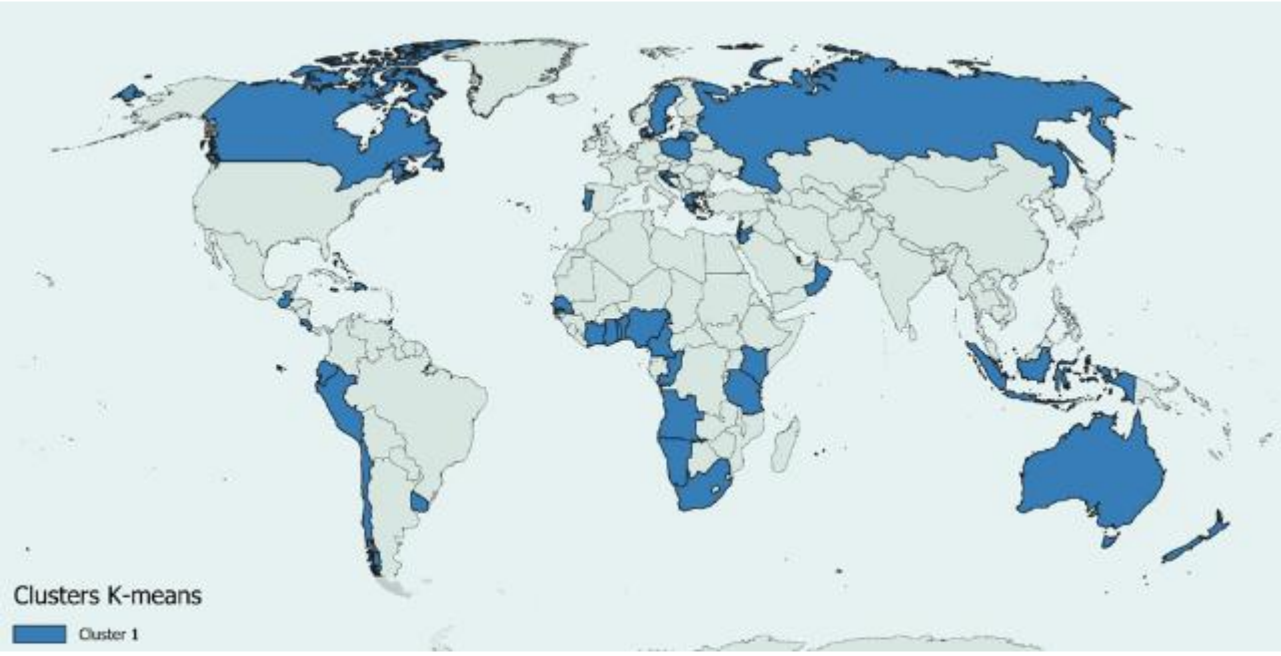
PC3, defined as a component of one-transhipment peripherality and regionally based service structure with a relatively high number of regional operators, appears to characterise Clusters 6 and 7 particularly strongly. This reflects the strong regional dimension of intra-Asian services, as both clusters are located in the South-East/Far East Asian area, close to China, within a region served by a large number of operators. PC3 also helps distinguish between Clusters 2 and 3. The markedly negative value of Cluster 2 on this component confirms its extremely peripheral condition and its dependence on a limited number of carriers, even for regional services.

With regard to PC2, defined as highly transhipment-related peripherality and a regionally based service structure with a limited number of operators, very high values confirm conditions of extreme marginality and vulnerability in terms of both service provision and network connectivity. The positive values recorded by Clusters 6 and 7 on this component should instead be interpreted in light of the strong regional service structure discussed above, rather than as evidence of maritime peripherality.

The various clusters will then be analysed, including through the results of the mean of the standardised values for the variables in each cluster, as shown in Table 20.

### 4.4.2.1. Intermediate cluster with a moderate semi-peripherality condition – Cluster 1

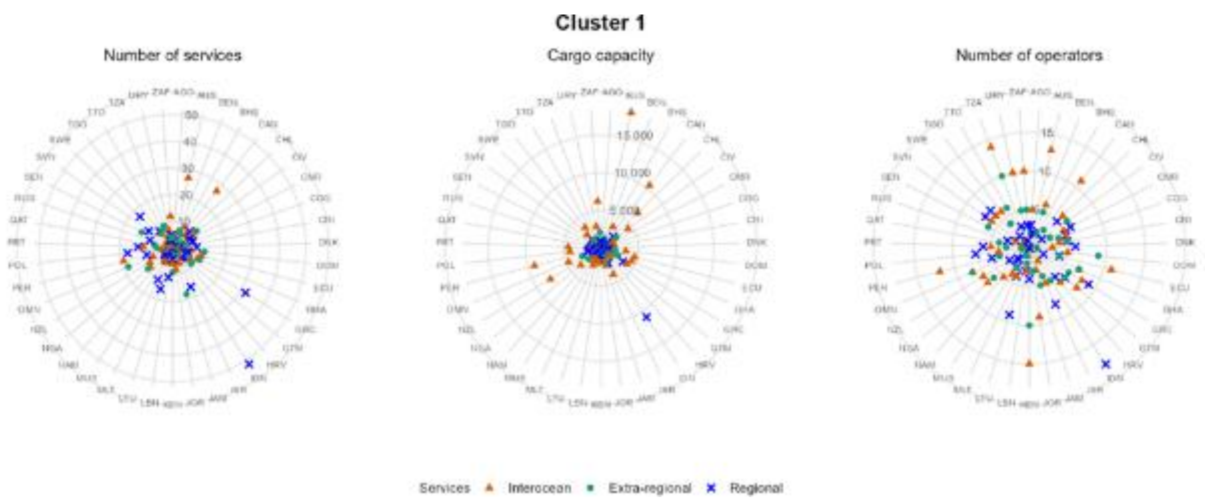
*Figure 54 Map of the countries of Cluster 1*




Cluster 1 displays a relatively moderate peripheric profile. In terms of standardized variables, it can be seen in Table 20, that it records slightly below-average values for most service and capacity indicators: interoceanic services (-0.142), interoceanic operators (0.267), interoceanic annual cargo capacity (-0.149), extra-regional services (-0.122), extra-regional operators (-0.061), extra-regional annual cargo capacity (-0.180), regional services (-0.162), regional operators (-0.031), and regional annual cargo capacity (-0.147).

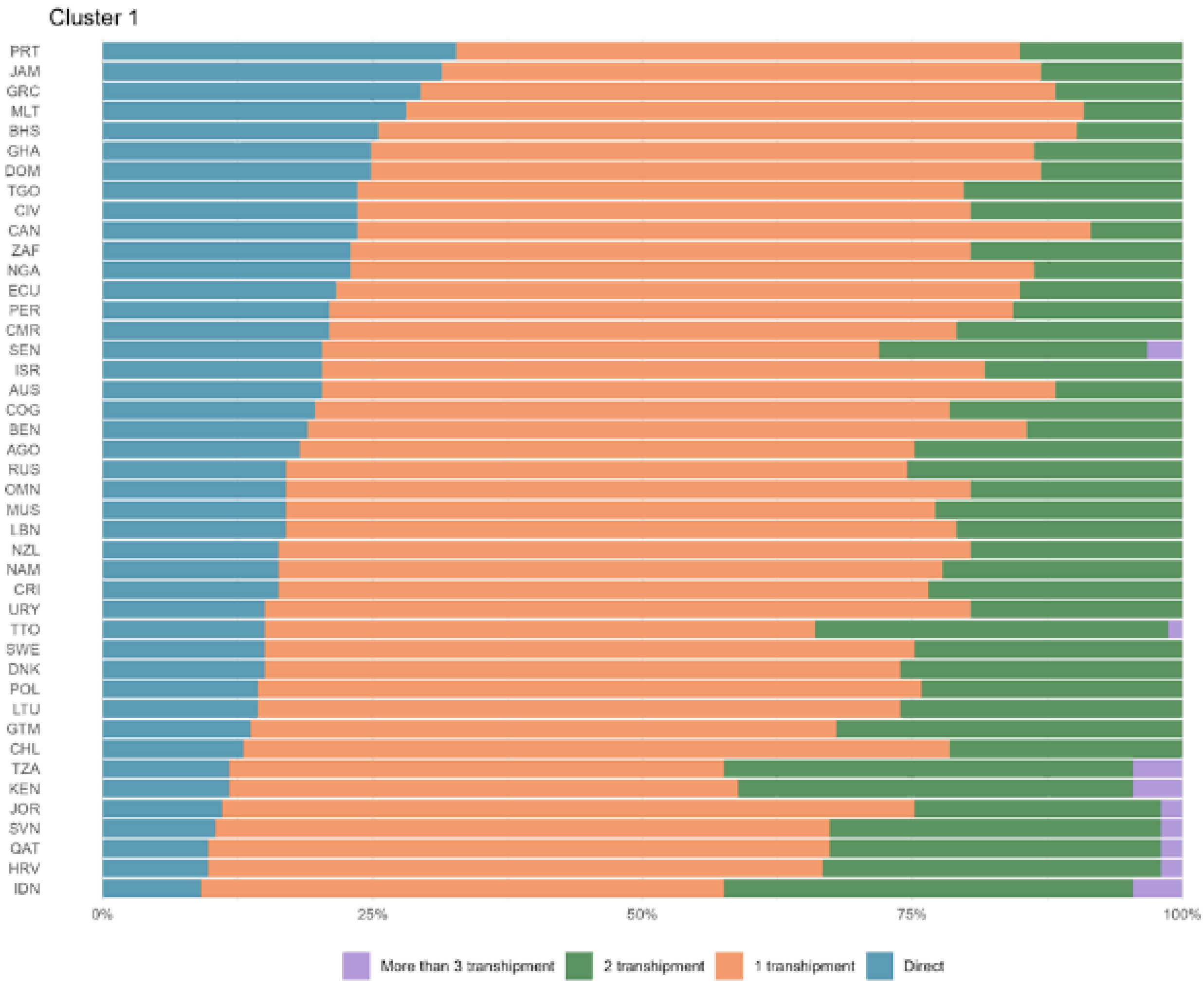
These values, which are close to the average, show that this cluster has an intermediate profile in terms of the condition of its scheduled services. Furthermore, as shown in Figure 55, almost all countries demonstrate a moderate capacity for inter-oceanic annual cargo capacity. Although these countries have a limited range of services, they nevertheless enjoy a degree of autonomy with regard to establishing direct global connections outside their own regional area. Furthermore, they tend to have access to a relatively consistent number of operators.

*Figure 55 Service structure of Cluster 1*



The cluster shows a positive value for countries requiring one transhipment (0.821), suggesting that these systems are not fully isolated but are mainly connected through relatively simple indirect connection. As confirmed also by the Figure 56. Furthermore, although there are a moderate number of direct connections, these tend to be greater than those of the two more peripheral clusters.

*Figure 56 Transhipment profile Cluster 1*

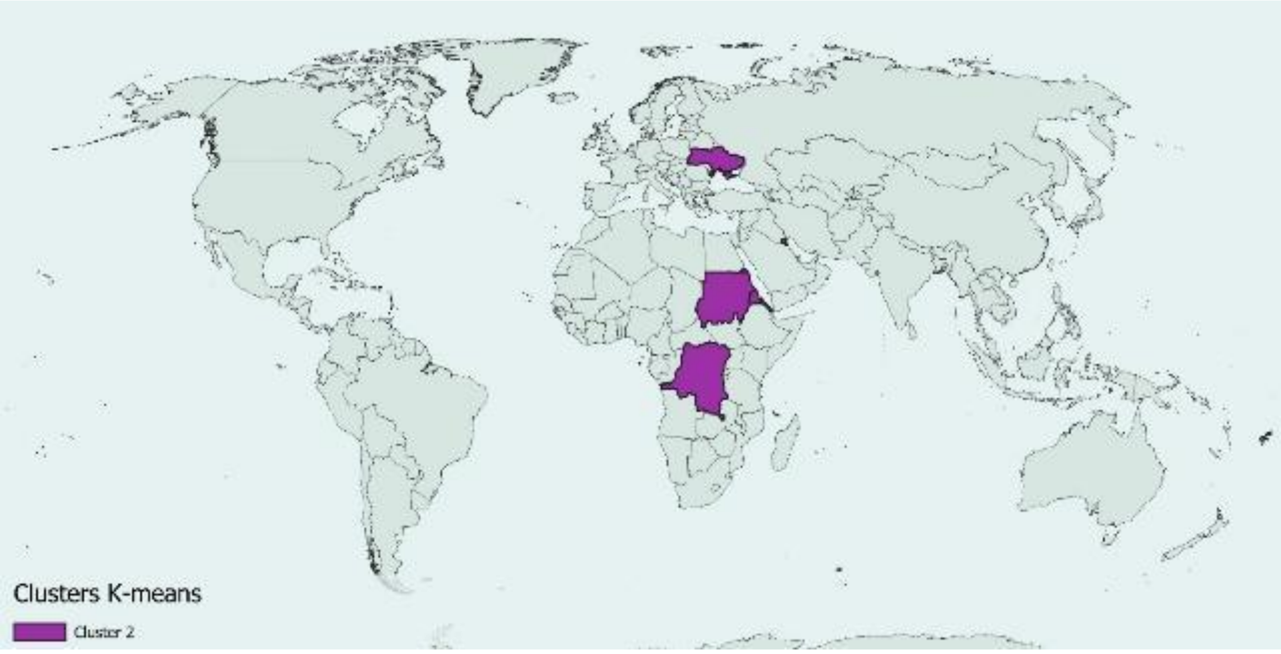



This interpretation is confirmed by the PCA scores. Cluster 1 has a near-average value on PC1 (0.081), a negative score on PC2 (-0.968), and a positive score on PC3 (0.504).

Overall, Cluster 1 can be interpreted as an “Intermediate cluster with a moderate semi-peripherality condition”. Moderately weak in terms of direct global maritime integration but not marginal at global level.

### 4.4.2.2. Extremely Peripheral and Highly dependent countries – Cluster 2

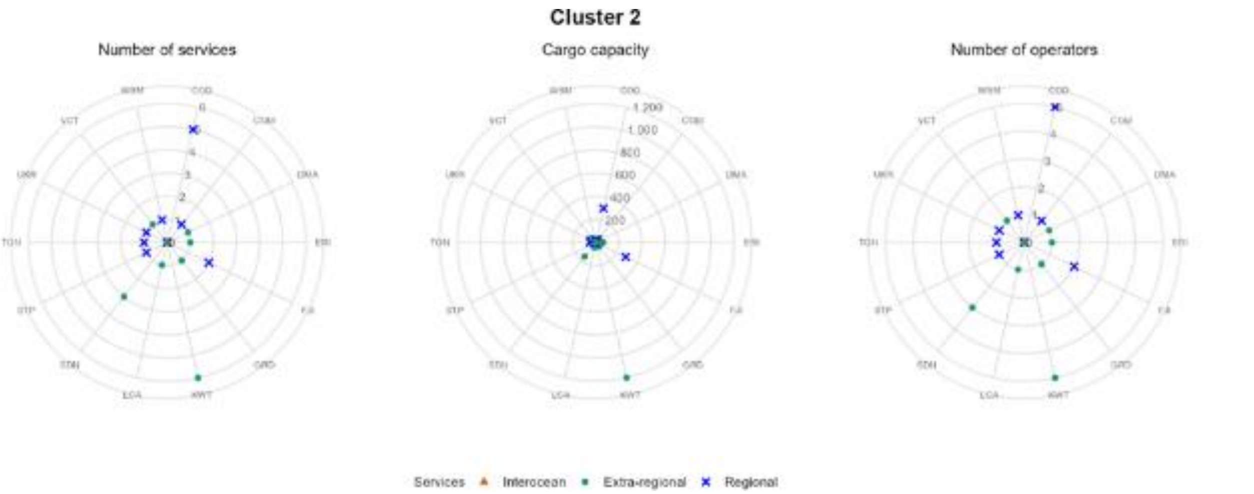
*Figure 57 Map of the countries of Cluster 2*




Cluster 2 represents the clearest case of maritime peripherality. The cluster has been defined as “Extremely Peripheral and Highly dependent countries”. As can be seen in the Table 20, it has strongly negative values for most direct connectivity, service, operator, and capacity indicators: interoceanic services (-0.464), interoceanic operators (-0.786), interoceanic annual cargo capacity (-0.291), extra-regional services (-0.550), extra-regional operators (-0.684), extra-regional annual cargo capacity (-0.402), regional services (-0.373), regional operators (-0.644), and regional annual cargo capacity (-0.260).

Figure 58 shows that these countries have extremely limited annual cargo capacity, most of which is provided by a single operator. Figure 58 shows that these countries have an extremely limited annual cargo capacity, with one or very few services, most of which are operated by a single carrier. These countries also do not have any inter-oceanic services.

*Figure 58 Service structure of Cluster 2*




It is also worth noting the country’s extremely peripheral position within the global maritime services network. As shown in Figure 59, most of these countries account for less than 25% of the world’s total, even after transhipment. It also records a very low value in Table 20 for directly connected countries (-0.917) and for countries requiring one transhipment (-2.070). This means that these countries not only have few direct connections, but are also linked to ports that are themselves already peripheral.

*Figure 59 Transhipment profile Cluster 2*

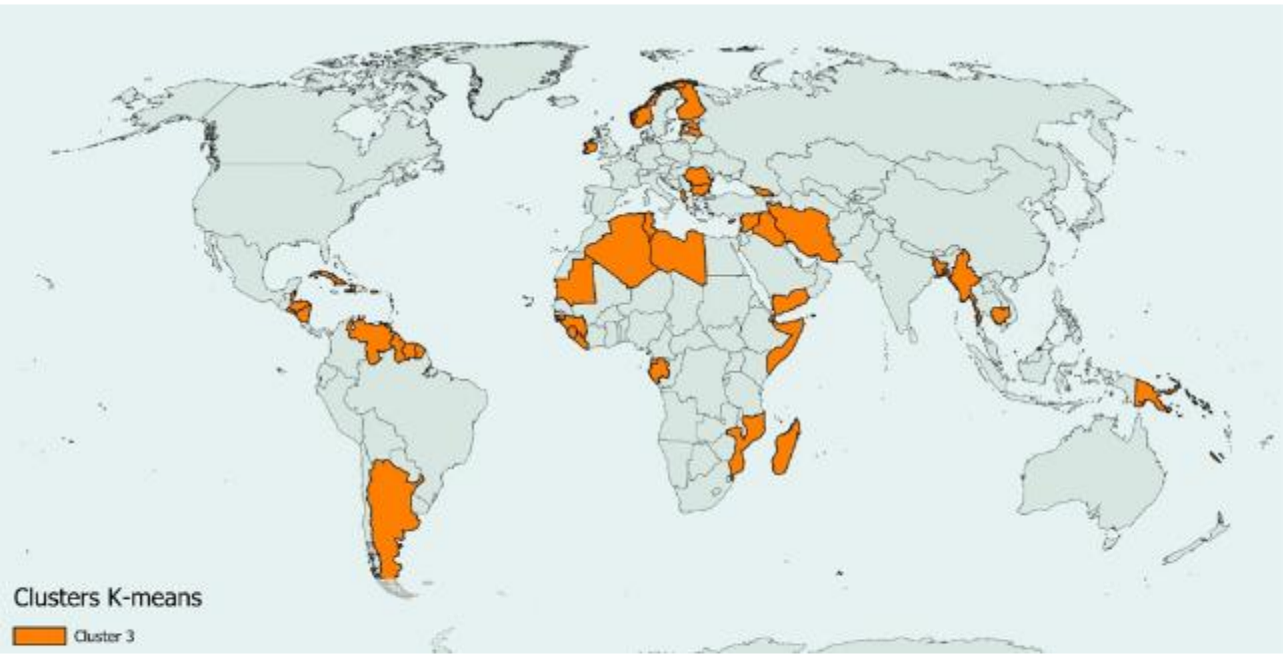

The PCA scores strongly reinforce this interpretation. Cluster 2 has a very negative PC1 score (-2.371), a very high positive PC2 score (2.321) and a PC3 a negative (-1.166).

Cluster 2 can therefore be interpreted as the most vulnerable and peripheral cluster. Countries in this group are weakly integrated into the maritime network, have limited direct access, and depend heavily on long and complex transhipment chains. This implies a structurally fragile maritime position and a high exposure to disruptions affecting intermediate hubs. Furthermore, these countries are heavily dependent on a very limited number of operators.

Ukraine is identified within this cluster. This confirms the country's extreme marginalisation following the outbreak of the war between Russia and Ukraine, as recently analysed by Polo Martin et al. (2025).

#### 4.4.2.3. Peripheral countries with a limited range connectivity and low-capacity network – Cluster 3

*Figure 60 Map of the countries of Cluster 3*



Cluster 3 also shows a generally weak maritime connectivity profile, although less extreme than Cluster 2. Table 20 records for this cluster negative values across most variables: interoceanic services (-0.444), interoceanic operators (-0.699), interoceanic annual cargo capacity (-0.287), extra-regional services (-0.416), extra-regional operators (-0.471), extra-regional annual cargo capacity (-0.363), regional services (-0.301), regional operators (-0.344), and regional annual cargo capacity (-0.228).

Figure 61 shows that these countries have a low annual capacity, limited mainly to regional or extra-regional services. However, the figures are less extreme than those for Cluster 2, and there is also a lower degree of dependence in terms of the number of operators

*Figure 61 Service structure of Cluster 3*

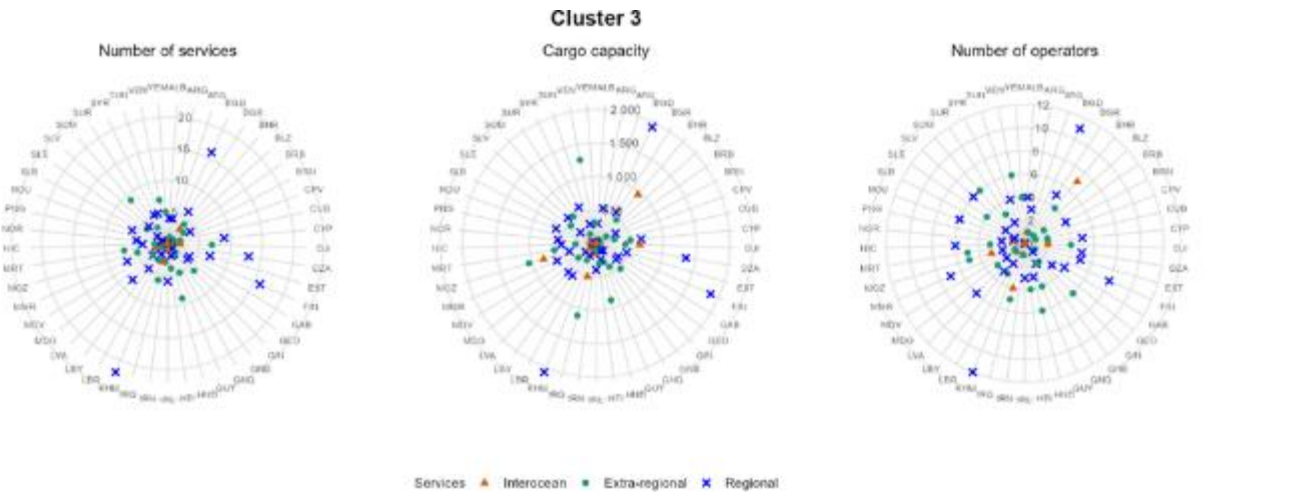
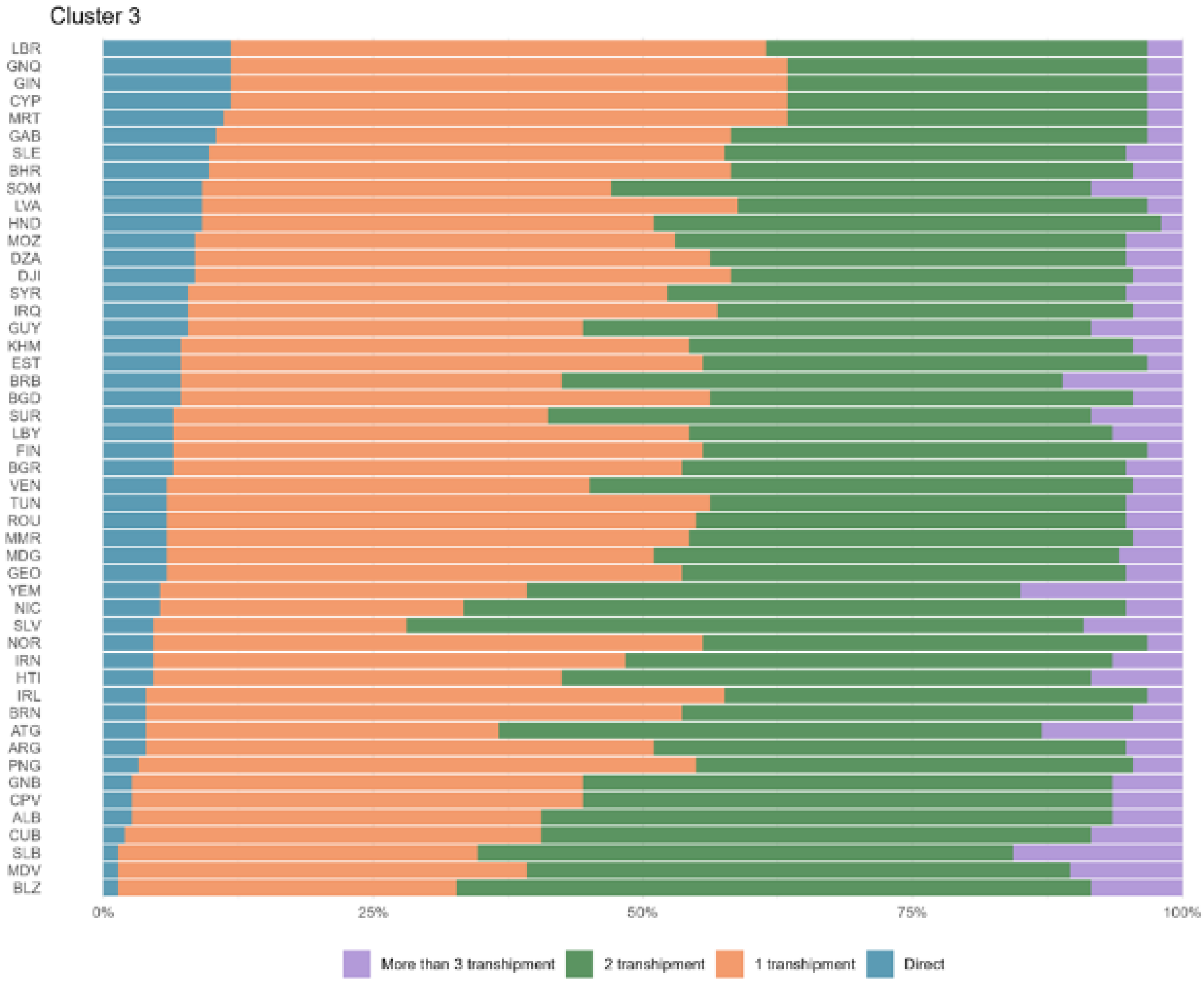



Figure 62 illustrates the marginal and peripheral nature of these countries in terms of transhipment, although this is less pronounced than in Cluster 2. There are very few direct connections, but a greater number of countries can be reached via a single transhipment. Furthermore, all countries show a modest, albeit minimal, number of countries that can be reached via three or more transhipments. Table 20 confirms that value for directly connected countries is also negative (-0.656). However, the value for countries requiring more than three transhipments is almost neutral (-0.003), indicating that this cluster is not primarily defined by this. These countries are therefore peripheral but linked to ports that tend to be of greater importance and better connected than those in cluster 2.

The PCA results provide a similar reading. Cluster 3 has a negative PC1 score (-1.320), indicating limited direct connectivity and a poorly developed maritime service structure. PC2 is almost neutral (0.064), suggesting that the cluster is not strongly associated with the specific form of extreme peripherality captured by PC2. PC3 is slightly positive (0.241), pointing to a modest degree of regional connectivity and a plurality of operators.

Cluster 3 can thus be interpreted as a “Peripheral cluster with a limited range connectivity and low-capacity network”, but not necessarily the most vulnerable one. Its main limitation is the overall weakness of services, operators, and cargo capacity, rather than an extreme peripherality in transhipment.

*Figure 62 Transhipment profile Cluster 3*

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### 4.4.2.4. Highly directly connected countries with strong global network integration - Cluster 4

*Figure 63 Map of the countries of Cluster 4*


Cluster 4 presents a clearly strong maritime connectivity profile. Table 20 show for this cluster high standardized values for interoceanic services (2.509), interoceanic operators (1.930), interoceanic annual cargo capacity (1.652), extra-regional services (3.336), extra-regional operators (2.339), and extra-regional annual cargo capacity (3.080). It also records positive values for regional services (0.975), regional operators (1.082), regional annual cargo capacity (0.583). These countries tend to be the ones with the strongest links via inter-oceanic and extra-regional services. Figure 64 shows that these countries have a large number of inter-oceanic services, and in the case of India, extra-regional services as well. It also shows that they are served by a large number of operators. The high volume of inter-oceanic and regional shipping services from countries such as Singapore and Malaysia confirms their status as countries with key hub ports for the region and globally. Examples include the Port of Singapore, Port Kelang and the Port of Tanjung Pelepas. Spain, too, has a profile that is well suited to the presence of major ports serving as transhipment hubs, such as Algeciras, and major ports serving both as transhipment hubs and gateways, such as Valencia and Barcelona.

The US, by contrast, has a very high number of inter-oceanic connections but very few regional connections and a limited number of extra-regional connections. This confirms the gateway role of American ports and reflects the country’s economic situation, which is heavily reliant on imports.

India’s classification within this cluster is particularly interesting. It is undoubtedly influenced by the high number of extra-regional services, yet is characterised by a high annual cargo capacity and served by numerous operators. Its geographical position, straddling the Middle East and the Far East, might suggest a role as a bridge between the regions. Furthermore, its status as a country experiencing rapid economic growth and the large number of coastal ports may further explain this classification.

*Figure 64 Service structure of Cluster 4*

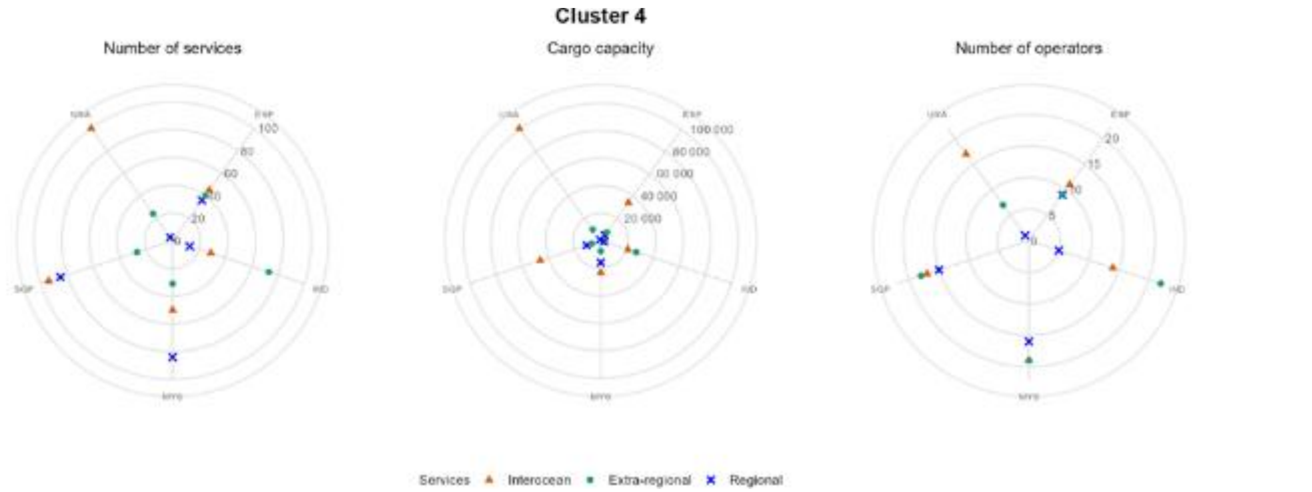
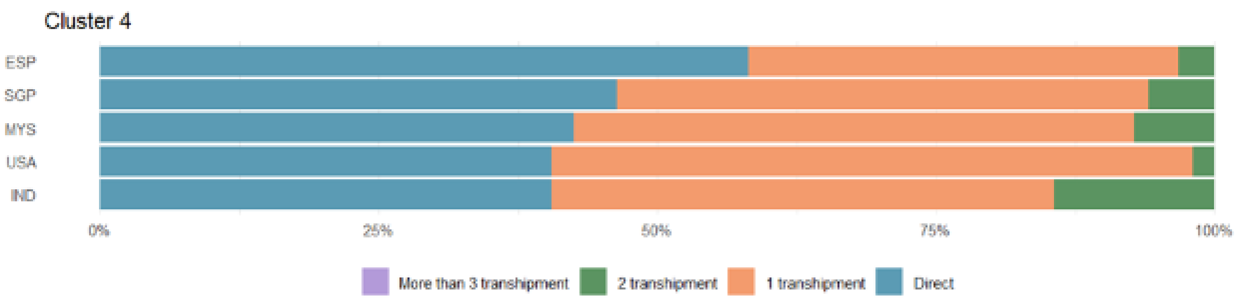



Table 20 show an high value in directly connected countries (2.227). At the same time, it has a negative value for countries requiring more than three transhipments (-0.648). As can be seen in Figure 65, these countries are directly connected to at least 40% of the countries in the network, and at least 80% of them can be reached via a single transhipment. Spain has the best profile globally in terms of directly connected countries. These figures confirm the extremely central condition of these countries.

The PCA scores confirm the structural meaning of this cluster with high PC1 score (6.202), a PC2 score is slightly negative (-0.457) and a PC3 score is strongly negative (-2.637), indicating that its connectivity is not primarily regional.

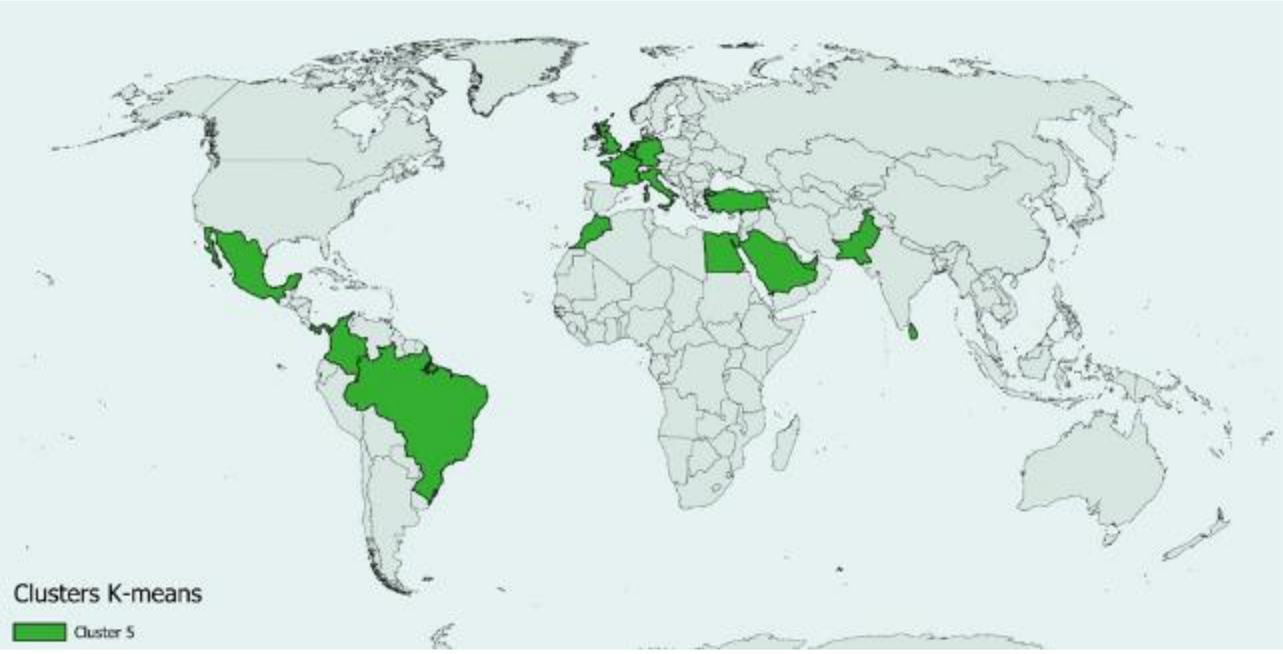
*Figure 65 Transhipment profile Cluster 4*




Cluster 4 can therefore be defined as Highly directly connected countries with strong global network integration. It is characterised by strong interoceanic and extra-regional service provision, high operator presence, and high cargo capacity.

### 4.4.2.5. Highly connected countries with high global accessibility - Cluster 5

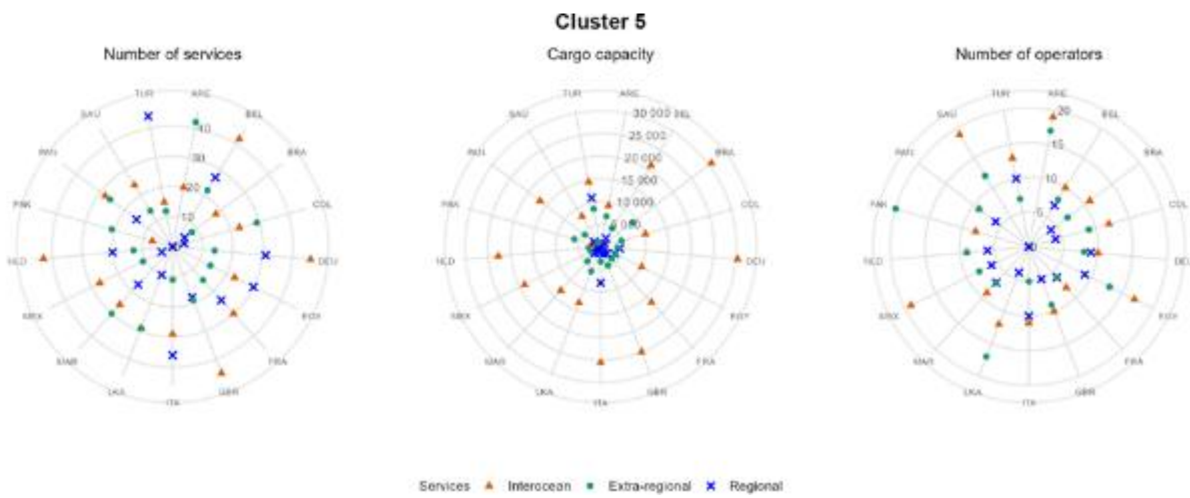
*Figure 66 Map of the countries of Cluster 5*




Cluster 5 is also higly integrated in the global maritime services, although less intensely than Cluster 4 and much less than Cluster 6. In Table 20 it records positive values for interoceanic services (0.842), interoceanic operators (1.324), interoceanic annual cargo capacity (0.439), extra-regional services (1.341), extra-regional operators (1.287), extra-regional annual cargo capacity (0.954), regional services (0.124), regional operators (0.320). Its regional annual cargo capacity is close to the overall mean (0.027).

Figure 67 shows that these countries have a high number of services, with a tendency towards all three types of service. All these countries have a higher annual cargo capacity on inter-oceanic routes. These two factors suggest, on the one hand, that these countries are highly integrated into the global market and, on the other, that some of their ports serve as regional hubs. The inclusion of Panama, Egypt, Morocco and the United Arab Emirates is largely attributable to the presence of key maritime infrastructure such as the Panama Canal and the Suez Canal in the case of the first two countries, and to the establishment of major hub ports near strategic straits such as the Strait of Gibraltar and the Strait of Hormuz. It is also worth noting that there is a moderate to high number of operators

*Figure 67 Service structure of Cluster 5*



In terms of connectivity, the Figure 68 show that this cluster is more diverse than the others. European countries and Morocco have a very high number of countries directly connected, whilst other countries such as Brazil, Saudi Arabia and Pakistan occupy a more intermediate position. However, all countries are able to reach at least 75% of other countries via a single transhipment. We can therefore describe this cluster as highly or moderately central.

The PCA scores indicate a similar but more moderate pattern than Cluster 4. Cluster 5 has a positive PC1 score (2.751), confirming a good level of direct connectivity and maritime service development. Its PC2 score is negative (-1.104), suggesting low dependence on complex transhipment chains. Its PC3 score is also negative (-1.084), indicating that the cluster is not primarily organised around regional feeder connectivity.

*Figure 68 Transhipment profile Cluster 5*


Cluster 5 can be interpreted as “Well connected countries with high global accessibility”. It benefits from direct connectivity and a relatively diversified service and operator structure, especially at interoceanic and extra-regional scales. However, it does not reach the level of structural centrality observed in Clusters 4 and 6.

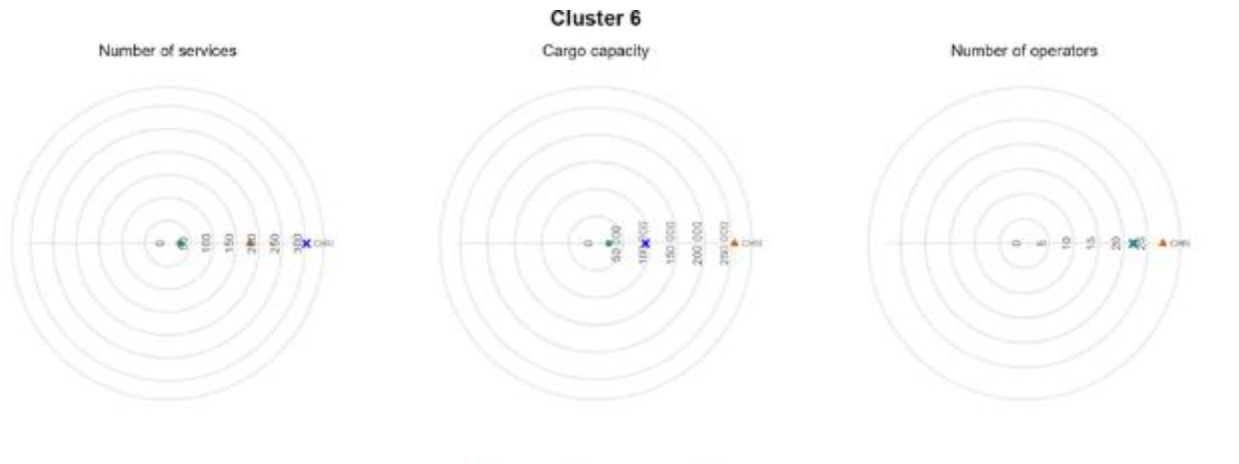
### 4.4.2.6. Primary Core Country – Cluster 6

*Figure 69 Map of the countries of Cluster 6*


Cluster 6 is by far the strongest and profile of core cluster. It records exceptionally high values for almost all variable on services and capacity: interoceanic services (7.949), interoceanic operators (4.090), interoceanic annual cargo capacity (10.716), extra-regional services (2.114), extra-regional operators (3.829), extra-regional annual cargo capacity (6.507), regional services (9.000), regional operators (3.697), and regional annual cargo capacity (10.810).

As can be seen from Table 20, the Chinese cluster has the highest values in the entire dataset for the service variables, with the sole exception of the number of extra-regional services. Furthermore, it can be seen that this cluster is served by the largest number of operators. As can also be seen from Figure 23, the values for each indicator are significantly higher than those for all the other clusters. The country exhibits characteristics of a core hub at both regional and global levels, demonstrating exceptional resilience in terms of both the range of services on offer and the number of operators.

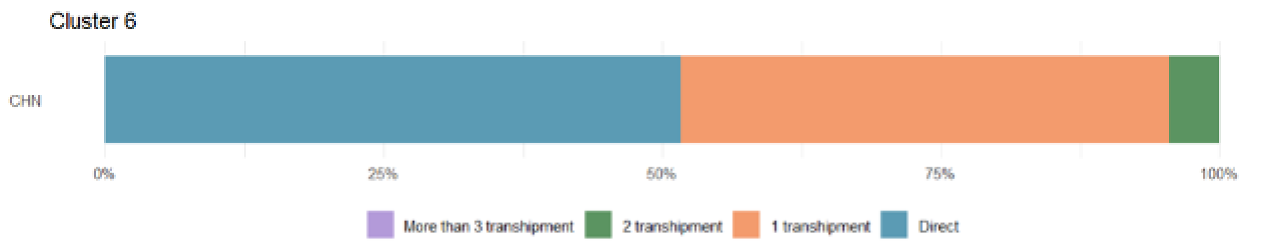
*Figure 70 Service structure of Cluster 6*




In terms of connectivity, it is highly connected and occupies a central position within the global maritime network. Table 20 shows the value for directly connected countries (2.672). As can be seen in Figure 71, the country can be reached directly from more than half of the countries, and with a maximum of one transhipment from 90% of them.

Its PCA profile is equally exceptional. Cluster 6 has an extremely high PC1 score (19.112), showing overwhelming direct connectivity, diversified operator presence, and very high cargo capacity across interoceanic, extra-regional, and regional scales. It also records a very high PC2 score (9.202) and a positive PC3 score (2.084).

*Figure 71 Transhipment profile Cluster 6*

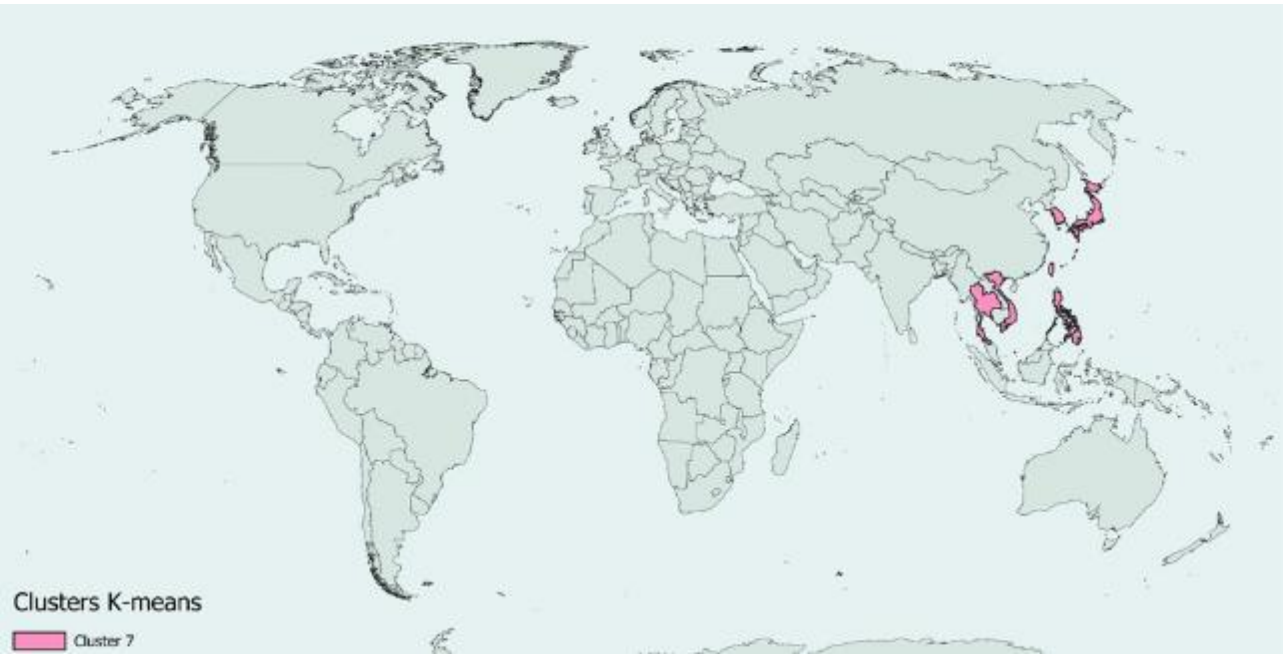



The positive PC2 score might appear counterintuitive, since PC2 is associated with transhipment-related peripherality. However, in the case of Cluster 6, this value should not be interpreted as evidence of vulnerability or marginality. Rather, it could be associated to the extreamly high quantinty of regional annual capacity and regional number of services. Also the high PC3 value further indicates that these hubs are also strongly embedded in regional networks and supported by significant regional service provision.

Cluster 6 can therefore be interpreted as the "Highly connected core Country". These countries or ports are not merely well connected; they are structurally central to the functioning of the maritime network. They combine direct global connectivity, large-scale cargo capacity, and a strong regional embeddedness.

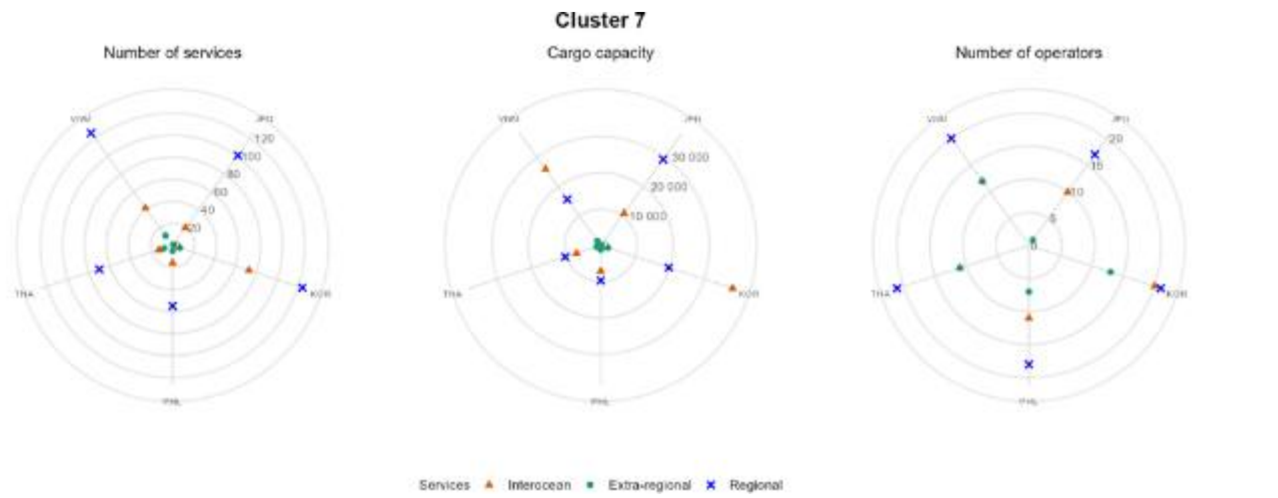
### 4.4.2.7. Moderatly well-connected countries with strong intra-asian regional integration – Cluster 7

*Figure 72 Map of the countries of Cluster 7*



Cluster 7 is characterized mainly for the strong inter-Asian connectivity condition and a high profile in terms of services. Table 20 shows a positive value for interoceanic services (1.052), interoceanic operators (1.378), interoceanic annual cargo capacity (0.447), regional services (2.382), regional operators (2.909), and regional annual cargo capacity (1.597). In contrast, its extra-regional services (-0.040) and extra-regional annual cargo capacity (-0.054) are around or slightly below the mean. With the exception of South Korea, which is home to one of the world's most important hub ports, namely the Port of Busan. For the other countries in the cluster, however, this situation is not directly attributable to hub functions, but rather to the strong global integration of their gateway ports and an high level of connectivity with neighbouring Asian countries.

*Figure 73 Service structure of Cluster 7*

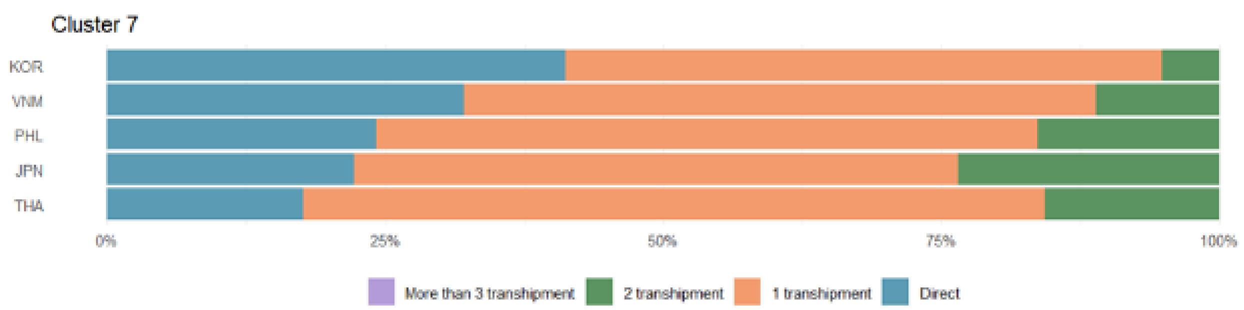



As can be seen from Figure 73, these countries all have a very high number of regional services and a high number of operators. Furthermore, they all have transoceanic services with high or medium-to-high annual cargo capacity.

In terms of connectivity, the cluster is moderately connected. Figure 74 records a positive value, (0.910), in countries directly connected that is less than the others well connected clusters, and a value for countries requiring one transshipment of (0.811) higher than the other three clusters. This confirms that these countries tend to be less central than clusters 4, 5 and 6. Figure 27 shows that all countries reach at least 75% of their destinations via a single transhipment, with South Korea having better direct connections than the other four countries.

The PCA scores confirm the regional orientation of this cluster. Cluster 7 has a positive PC1 score (3.737), PC2 is moderately positive (0.594), and most importantly, PC3 is strongly positive (2.315), which points to a regionally embedded maritime structure supported by a relatively high number of regional operators and one-transhipment connections

*Figure 74 Transhipment profile Cluster 7*




Cluster 7 can therefore be interpreted as Moderately well-connected countries with strong intra-asian regional integration. These systems are globally integrated but not extremely central with a huge and resilient regional network.

#### 4.4.2.8. Islands and coastal countries outside the liner network

*Figure 75 Map of the Islands and coastal countries outside the liner network*

Finally, this analysis reveals an eighth "hidden cluster": namely, that of countries completely excluded from the network of container liner services. As can be seen in Table 21, most of these are small islands or archipelagos of small islands, or countries with a limited coastline, such as Bosnia and Herzegovina and The Gambia. There are also coastal countries of a certain size, such as Montenegro and the Democratic People's Republic of Korea, as well as larger island nations such as Iceland and Timor-Leste.

*Table 21 List of islands and coastal countries outside the liner network*

| ISO 3166-1 alpha-3 | Name |
|---|---|
| BIH | Bosnia and Herzegovina |
| PRK | Democratic People's Republic of Korea |
| GMB | Gambia |
| ISL | Iceland |
| KIR | Kiribati |
| MHL | Marshall Islands |
| FSM | Micronesia (Federated States of) |
| MCO | Monaco |
| MNE | Montenegro |
| NRU | Nauru |
| PLW | Palau |
| KNA | Saint Kitts and Nevis |
| SYC | Seychelles |
| TLS | Timor-Leste |
| TUV | Tuvalu |
| VUT | Vanuatu |

Although the case of North Korea is well documented (Ducruet, 2007, 2008) and is due to the country's geopolitical isolation, it cannot be said that all these countries are completely devoid of maritime services and connections, the fact that they are not served by any of the top 30 global shipping companies however manifest their extreme vulnerability and marginalisation in terms of maritime transport.

## 4.5 Peripherality, dependency, vulnerability

In this section, I shall attempt to summarise the characteristics of the service networks for each cluster of countries in light of the concepts of peripherality and dependency.

The concept of peripherality can be interpreted in two ways. On the one hand, there is topological peripherality within the network, and thus the number of transhipments required to reach all other countries in the network. On the other hand, the fact that this aspect is obviously linked to the structure of services.

The absence or limited capacity for inter-oceanic or extra-regional services forces the country to rely on hub ports in other countries for its global connections. This makes the country dependent both on third country's policy for its connections and on the commercial choices of the operators providing these services. Countries with few services and few operators providing them are therefore highly dependent.

Conversely, countries with all three types of services are more independent from third countries when it comes to their global transport. Furthermore, a large number of operators also means greater choice and, presumably, greater competition in the market. It is possible therefore use the previous clustering to define a hierarchy in terms of dependency and peripherality.

This hierarchy is represented in the Figure 76. As can be seen, it is the northern hemisphere that is where most of the central and independent countries are concentrated. Brazil is the only country south of the Equator (the red line) with a container shipping service structure that makes it both independent and central. However, if we exclude small states with micro-insular characteristics, we see that the northern hemisphere exhibits a greater degree of polarisation between countries. This is a factor that we can certainly link to the high degree of hierarchy within global maritime networks based on the hub'n'spoke structure, as has already been demonstrated by various scholars (Ducruet and Notteboom, 2012, Xu et al, 2015, McCalla et al, 2004).

*Figure 76 Map of clusters classified by the level of centrality and dependency*

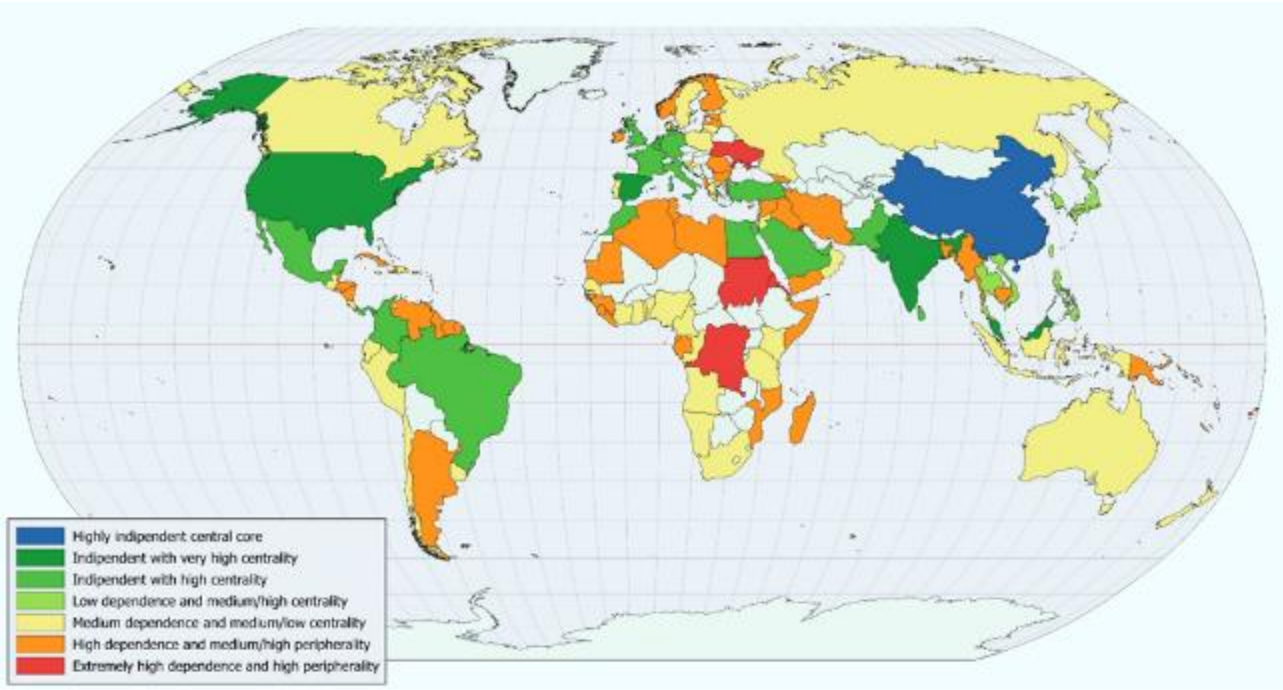



*Table 22 Comparison of cluster vulnerability*

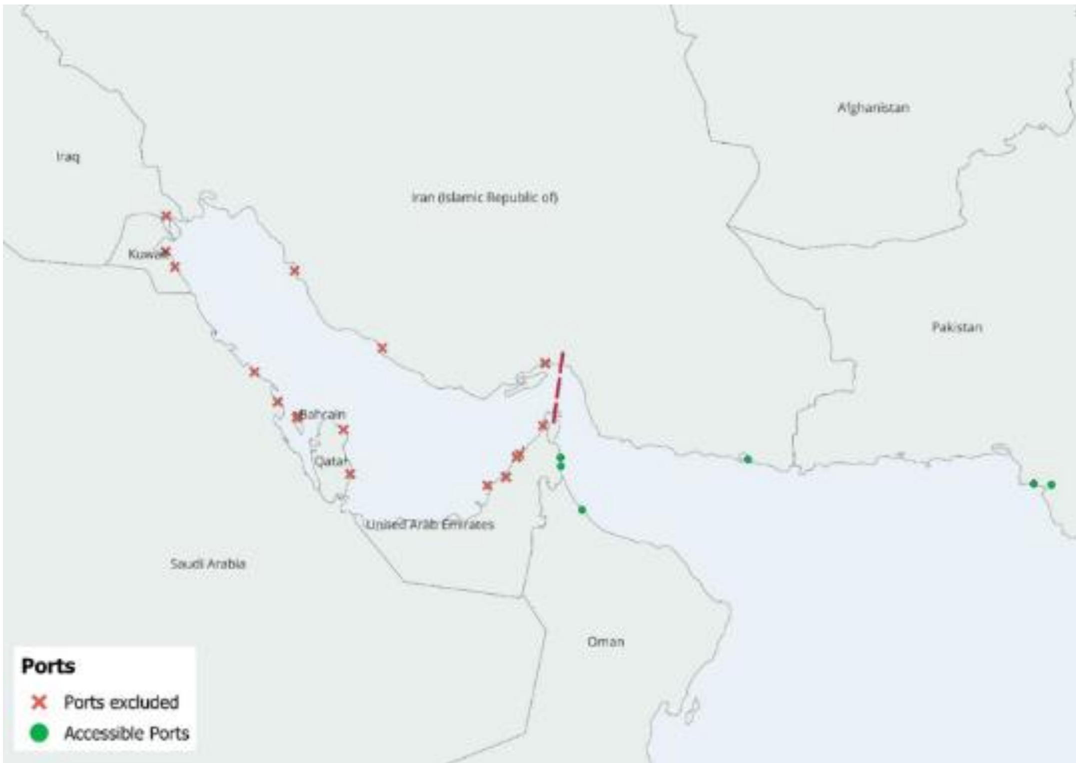
| Clusters | Service structure vulnerability | Operator dependence | Network peripherality |
|---|---|---|---|
| **2** | Very high | Very high | Very high |
| **3** | High | High | high |
| **1** | Medium | Medium | Medium |
| **7** | Medium-low | Low regionally, Medium-low globally | Medium/Low |
| **5** | Low | Low | Low |
| **4** | Very low | Low | Very low |
| **6** | Minimal | Very low | Central |

By combining these two analyses of dependency and peripheral status, we can therefore hypothesise that the maritime services infrastructure exhibits varying degrees of vulnerability as can be seen in Table 22. In this approach, a country's maritime infrastructure is not defined as vulnerable in relation to individual types of routes or services, but rather in relation to its ability to rely on various alternatives to ensure access to international maritime transport. If we continue with the interpretative approach outlined above, we can see that, apart from the high vulnerability of small micro-island nations, the strong polarisation in the Northern Hemisphere is also reflected in greater vulnerability for the more peripheral states.

## 4.6 Hormuz crisis effects

The previous assessment of vulnerability, however, should be considered solely in relation to the structure of the services passing through the country. This type of analysis does not take into account, at least directly, the vulnerability issues linked to geographical conditions, such as the closure of maritime choke points. In an attempt to examine this issue in the light of the recent military conflict between the United States and Iran, and the resulting Iranian blockade of the Strait of Hormuz and subsequent US counter-blockade, the immediate effects of this scenario have been analysed in the context of the scheduled services announced by the shipping companies in early March. The scenario analysis was carried out in two ways: firstly, by excluding from the service rotations the ports in the Persian Gulf shown in Figure 77, which are situated on the inner side of the Strait of Hormuz where the channel is narrowest; and secondly, as shown in Figure 79, by also including the ports of the United Arab Emirates and Iran located outside the strait and the port of Sohar in Oman. In this way, the scenario in which services are maintained but do not call at these ports was assumed, and the impact of this on all the countries from the previous analysis was observed in terms of the number of transhipments required to reach the others.

*Figure 77 First scenario of Hormuz blockage*




In the first scenario, we can see that the four countries listed in the Table 23 (Qatar, Bahrain, Iraq and Kuwait) results completely excluded from the network.

*Table 23 Countries excluded by the first scenario*

| ISO 3166-1 alpha-3 | Countries |
|---|---|
| **QAT** | Qatar |
| **BHR** | Bahrain |
| **IRQ** | Iraq |
| **KWT** | Kuwait |

However, as shown in Figure 78, very few countries worldwide are actually affected in terms of transhipment distance. The countries outside the Persian Gulf that are affected are Yemen, Somalia and Portugal. The first, in addition to losing the four countries excluded in terms of direct connections and connections via one transhipment, sees the number of countries reachable via two transhipments increase by two, whilst for the second this increases by only one. Portugal, on the other hand, despite its distance from the region, sees this number of countries increase to three. The United Arab Emirates has seen a significant impact in terms of connectivity, with the number of countries reachable via a single transhipment rising by 14, and an increase of two countries in the third category. Saudi Arabia, on the other hand, has seen an increase of just two countries reachable via a single transhipment and two via two transhipments. Finally, Iran has seen an increase of two countries reachable via two transhipments.

*Figure 78 Impact on countries in transhipment distance (First scenario)*

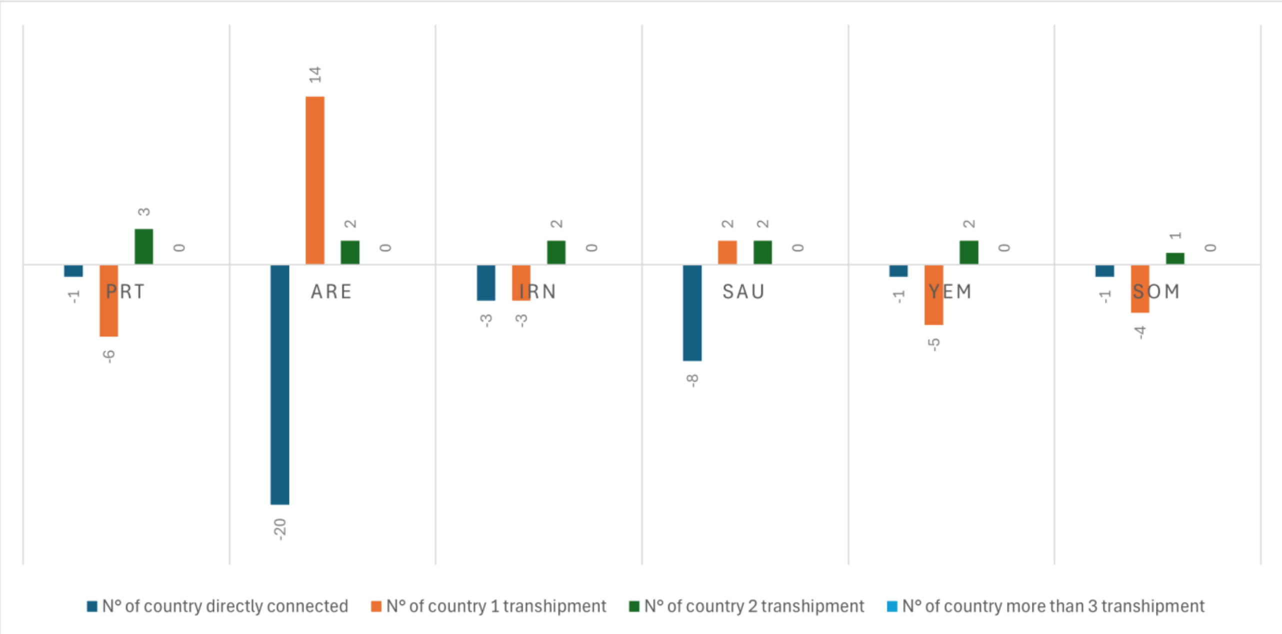
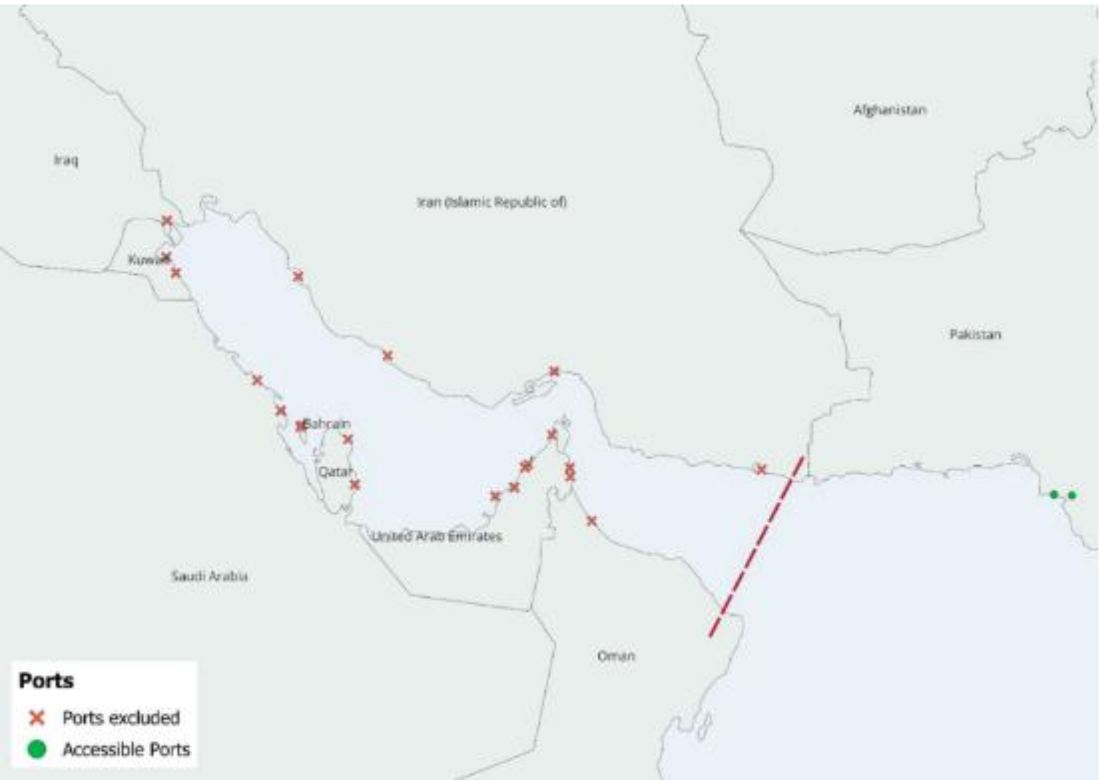



*Figure 79 Second scenario of Hormuz blockage*




In the second scenario, however, the number of excluded countries rises to six with the addition of the United Arab Emirates and Iran, as shown in the Table 24.

If we look at Figure 80, however, we can see that no other countries are affected by the exclusion of these ports, and as regards the countries affected, only Iran and the USA have been excluded from the connected countries.

*Table 24 Countries excluded by the second scenario*

| ISO 3166-1 alpha-3 | Countries |
|---|---|
| **ARE** | United Arab Emirates |
| **QAT** | Qatar |
| **BHR** | Bahrain |
| **IRQ** | Iraq |
| **IRN** | Iran |
| **KWT** | Kuwait |

*Figure 80 Impact on countries in transhipment distance (second scenario)*


An analysis of these two scenarios suggests that, at the level of the global maritime services network, the closure of the Strait of Hormuz appears to have a relatively limited impact on global connectivity for container liner services. This is despite the presence of a major transhipment hub such as Jebel Ali in the United Arab Emirates. This confirms the remarkable resilience of the global maritime network.

Looking at these scenarios, we can therefore see that the classification set out earlier in this chapter is partly confirmed by this analysis. If we look at the first scenario, we can see that two of the four excluded countries are in cluster 3 and are therefore considered highly vulnerable, and one is in cluster 2 and is therefore extremely vulnerable. Qatar, on the other hand, is classified in cluster 1, meaning it is vulnerable but to a moderate degree. If, on the other hand, we look at the countries outside the Gulf, we see that the countries most severely affected in the region, namely Yemen and Somalia, are both classified in the third cluster, and this crisis is exacerbating their marginalisation. It is interesting to note that Portugal is the only country outside the region to be affected in terms of transhipment distance. Although classified in cluster 1, it appears, for many variables, to be on the borderline of this cluster. However, the fact that it has been affected by this crisis can be seen as confirmation of its correct classification.

Finally, if we look at the countries bordering the gulf that maintain their connection to the maritime network, we can see from Table 25 that Saudi Arabia and United Arab Emirate, despite being affected by the crisis , particularly ARE, retain good resilience, with both inter-oceanic and extra-regional services and a high cargo capacity. Furthermore, as can be seen in Figure 78, ARE has been affected in terms of direct connectivity, but maintains connections to major ports that allow it to connect to most countries with a single transhipment. Iran, too, despite being in cluster 3, retains a degree of resilience, albeit minimal, even though it remains dependent on a single shipping company and has limited annual capacity. However, as we have seen, the most extreme scenario 2 completely undermines the resilience of ARE and IRN, resulting in greater vulnerability due to the geographical factors affecting the former compared to the SAU that remains with the same impact as the first scenario.

*Table 25 Impact on service structure of the gulf countries not excluded from the network*

| Services structure | ARE | IRN | SAU | SAU (2) |
|---|---|---|---|---|
| *N° of services - Interocean* | 5 | 1 | 17 | 17 |
| *N° of operators - Interocean* | 6 | 1 | 14 | 14 |
| *Annual cargo capacity - Interocean* | 1598904 | 79500 | 4190657 | 4190657 |
| *N° of services - Extra regional* | 9 | 1 | 11 | 8 |
| *N° of operators - Extra regional* | 7 | 1 | 8 | 11 |
| *Annual cargo capacity - Extra regional* | 1522107 | 15900 | 769825 | 769825 |
| *N° of services - Regional* | 0 | 0 | 0 | 0 |
| *N° of operators - Regional* | 0 | 0 | 0 | 0 |
| *Annual cargo capacity - Regional* | 0 | 0 | 0 | 0 |

## 4.7 Conclusions

This chapter has examined the unequal integration of countries into the global liner shipping service network as a specific form of vulnerability within the maritime transport system. Rather than approaching maritime connectivity only through aggregate measures of capacity, port calls or direct links, the analysis has focused on the structure of liner services at the country level, distinguishing between interoceanic, extra-regional and regional services. This approach makes it possible to interpret connectivity not simply as the presence of maritime services, but as a relational condition shaped by the scale of service provision, the number of operators, cargo capacity, direct connections and transhipment requirements.

The results confirm the strongly hierarchical structure of the global container shipping network. A limited number of countries occupy highly central positions, benefiting from diversified service structures, high annual cargo capacity, a large number of direct connections and the presence of several operators. These countries are less dependent on individual carriers or foreign hub ports and therefore display a more resilient maritime position. At the opposite end of the hierarchy, several countries are characterised by very limited service provision, low capacity, few operators and a strong dependence on indirect connections. In these cases, vulnerability derives not only from weak access to maritime services, but also from the lack of alternative routes and operators through which international maritime transport can be maintained.

The PCA has shown that the key factors determining a country's service structure and connectivity stem from its ability to provide a wide range of services or, conversely, from its reliance on regional services and the degree of marginalisation linked to the country's distance in terms of transhipment. The first component captures strong direct connectivity and a broadly developed global service structure. High values on this component identify countries with extensive service provision across different geographical scales, significant operator diversity and substantial cargo capacity. The second component captures a more problematic form of transhipment-related peripherality, associated with the need to reach many countries through long and complex transhipment chains and the limitation in regional services and few operators. The third component identifies a semi-peripheral and regionally embedded form of connectivity, in which countries are relatively well integrated into regional networks but remain more dependent on hub ports for wider global access.

The k-means clustering analysis further demonstrates that these dimensions combine into distinct national profiles. China emerges as an exceptional case, forming a primary core cluster characterised by extremely high values across almost all indicators. Other central clusters include countries with strong interoceanic and extra-regional service provision, high direct connectivity and diversified operator presence. These countries tend to be located along major historical shipping corridors or near strategic maritime passages and often host important gateway or transhipment ports. Their position within the network provides a high degree of redundancy and therefore reduces their exposure to disruptions affecting individual services or operators.

By contrast, the most peripheral clusters are composed of countries with weak service structures, low cargo capacity and limited operator presence. The most vulnerable group is not merely poorly connected; it is also connected through ports that are themselves relatively peripheral. This creates a condition of compounded peripherality, in which countries depend on long transhipment chains and have limited capacity to substitute routes or operators. A second peripheral group displays a less extreme profile: these countries remain weakly served, but their connections generally pass through more central ports, reducing the degree of exposure compared with the most peripheral cluster. An intermediate cluster occupies a semi-peripheral position, with moderate levels of service provision and a stronger reliance on one-transhipment connections.

The analysis also highlights the specific role of regional embeddedness. Some countries, particularly in East and Southeast Asia, are not among the most globally central countries, but benefit from dense regional liner service networks and a relatively high number of regional operators. In these cases, regional integration can mitigate vulnerability by providing service redundancy.

A further important finding concerns the group of coastal countries that are not served by any of the top 30 container shipping companies included in the analysis. These countries form a kind of hidden cluster outside the reconstructed liner network. Although their absence from this dataset does not necessarily imply a complete lack of maritime transport services, it does indicate extreme marginality in relation to the global container shipping system operated by the largest carriers. This condition is particularly relevant for small island states and other coastal countries with limited integration into global liner networks.

The discussion of vulnerability shows that peripherality can be understood in two complementary ways. The first is topological peripherality, measured by the number of transhipments required to reach other countries in the network. The second is service-structural peripherality, linked to the absence or weakness of interoceanic and extra-regional services. Countries lacking these services must rely more heavily on foreign hubs and on the commercial strategies of carriers that decide whether, how and where to operate feeder or regional connections. In this sense, vulnerability is not defined by the presence or absence of a single type of service, but by the capacity of a country to rely on multiple alternatives in order to maintain access to international maritime transport.

The analysis also reveals a clear hemispheric imbalance. Most central and highly connected countries are located in the Northern Hemisphere, along the main East-West maritime corridors. By contrast, countries in the Southern Hemisphere tend to occupy more intermediate or peripheral positions, with Brazil representing the main exception. This suggests that inequalities in liner shipping connectivity are not only network-based, but also reflect broader geographical asymmetries in the organisation of global trade.

The scenario analysis of the Strait of Hormuz provides a useful test of this vulnerability framework. At the global level, the simulated exclusion of ports located inside or around the Strait produces relatively limited effects on the overall topology of the container liner network. This suggests that, despite the strategic importance of the Strait of Hormuz, the global liner shipping network displays a considerable degree of resilience in terms of container service connectivity. However, the impact is much more severe for the countries directly located in the Gulf and for a small number of already peripheral countries outside the region. In the first scenario, Qatar, Bahrain, Iraq and Kuwait are excluded from the network; in the second scenario, the exclusion extends to the United Arab Emirates and Iran. These results show that a disruption can have limited systemic effects at the global scale while producing very significant consequences for specific countries.

The Hormuz scenario therefore partly confirms the vulnerability hierarchy identified through the clustering analysis. The countries most severely affected are generally those already characterised by weak connectivity, limited service alternatives or a peripheral position within the network. At the same time, the case of countries such as the United Arab Emirates shows that geographical exposure to a choke point can create forms of vulnerability that are not fully captured by service-structure indicators alone. This suggests that maritime vulnerability depends on both network topology and geographical location. A country may be highly connected in normal conditions, yet remain exposed to disruption if its connectivity is concentrated around a narrow maritime passage or a small number of strategic ports.

Overall, the chapter shows that unequal access to liner shipping services is a central dimension of maritime vulnerability. Central countries benefit from direct access, service diversity and operator redundancy. Peripheral countries, by contrast, are more exposed to service withdrawals, carrier restructuring, hub disruption and longer transhipment chains.

The contribution of this chapter is threefold. First, it provides a country-level reconstruction of the global liner shipping service network based on the service rotations of the top 30 container shipping companies. Second, it combines service indicators, operator presence and topological distance in order to identify different configurations of maritime vulnerability. Third, it shows how the resulting classification can be used to interpret the uneven effects of a disruption scenario affecting a major maritime choke point.

Several limitations should be acknowledged. The analysis is based on scheduled liner services observed at a specific point in time and therefore captures the declared structure of the network rather than actual vessel movements, delays, blank sailings or effective capacity utilisation. Furthermore, a different division of port regions or a different classification of services could alter the results of the classification to some extent. Moreover, the focus on the top 30 carriers may underestimate the role of smaller regional or niche operators in some peripheral markets. Future research could address these limitations by comparing scheduled services with AIS-based vessel movements, extending the analysis over multiple years, and integrating freight rates, trade flows, port performance indicators or measures of schedule reliability. Further work could also examine how alliance restructuring, carrier consolidation and geopolitical disruption reshape national vulnerability profiles over time. Furthermore, an analysis of the role played by the various carriers can help to provide a better understanding of the significance of the carriers' market strategies and the effects of dependency or advantage for different countries. In addition, if this study were to be conducted over a longer period, it could provide useful insights into the long-term impact of major global infrastructure projects such as China's Maritime Silk Road, one of whose objectives was precisely to improve maritime connectivity for the participating countries.

Despite these limitations, the findings clearly show that maritime connectivity is an unevenly distributed strategic resource. The structure of liner shipping services shapes countries' ability to participate in global trade, absorb shocks and reduce dependence on foreign hubs or dominant carriers. Understanding these inequalities is therefore essential for assessing the resilience of national maritime systems and for developing policies aimed at improving connectivity, diversifying service options and reducing structural dependence within the global maritime transport network.

# 5. Conclusions

This thesis has investigated the vulnerability of maritime container transport in an era increasingly characterised by global shocks. By focusing on the concepts of peripherality, dependency and vulnerability, the research has shown that disruptions in container shipping do not affect ports, regions and countries in a homogeneous way. Rather, their impacts are mediated by the structural position that each port or country occupies within liner shipping networks and may also be influenced by the degree of dependence on hub ports and shipping operators, and by the capacity to rely on alternative connections when established routes are disrupted.

The thesis has adopted a multiscalar perspective, analysing maritime container transport at three geographical levels. The first chapter examined the impact of the Red Sea crisis on the Italian container port system. The second chapter investigated the evolution of hub dependency in the Mediterranean, with particular attention to the position of Italian ports. The third chapter extended the analysis to the global scale, assessing the uneven distribution of maritime connectivity among countries and testing this framework through a disruption scenario related to the Strait of Hormuz. Taken together, these three empirical perspectives demonstrate that vulnerability in maritime container transport is highly connected to the hierarchical organisation of liner shipping networks.

The first main finding of the thesis is that maritime shocks tend to reinforce pre-existing spatial inequalities within port systems. The analysis of Italian ports during the Red Sea crisis showed that the disruption of the Suez-Red Sea corridor did not produce a uniform decline across the national port system. Instead, its effects were territorially differentiated. While several ports experienced reductions in port calls, services and deployed capacity, others were able to maintain or even improve their relative position. In particular, Tyrrhenian ports generally proved more resilient than Adriatic ports, although with important internal differences. Gioia Tauro, La Spezia, Naples and Vado Ligure recorded positive competitive effects, while Genoa, Livorno, Venice, Ravenna, Trieste and Salerno showed weaker or negative results. This shows that, whilst geographical location is certainly a factor in potential peripheralisation, the structure of services is also a decisive factor. The ability to attract or retain regional and extra-regional services, the role of transhipment functions, and the strategies of individual carriers are equally important.

A second important finding concerns the growing relevance of regional connectivity in a context of disrupted long-distance routes. The Red Sea crisis reduced the relative position of Mediterranean ports within Europe-Asia shipping services. In this context, ports that strengthened intra-Mediterranean and Gibraltar-related services were better able to absorb the shock. Conversely, ports that lost regional services tended to experience negative competitive outcomes. This suggests that regional maritime networks may operate as a form of resilience, especially when direct extra-regional connections are weakened. However, this resilience is unevenly distributed and depends on the capacity of ports to remain embedded in the commercial strategies of major liner operators.

The overall findings appear to reinforce certain observations made in the second chapter, where it was noted that, in response to crises, maritime operators tend to organise cargo flows more closely around the hub-and-spoke model, in this case to the benefit of Gioia Tauro. Furthermore, it is suggested that the ability of lower-tier ports to integrate more fully into regional services may act as a factor in their resilience to such shocks, partly confirming the suggestions arising from the density of Italian networks discussed in the subsequent chapter.

The second chapter in fact demonstrated that these short-term findings can be interpreted against the background of a longer-term transformation of the Mediterranean container shipping network. The analysis of hub dependency between 2000 and 2023 showed a progressive consolidation of a hierarchical hub-and-spoke structure. Hub functions have become increasingly concentrated in a limited number of Mediterranean ports, particularly in the western Mediterranean and in selected eastern Mediterranean nodes. Within this structure, Italian ports occupy differentiated positions. Gioia Tauro maintains a relevant transhipment function, while several gateway ports have experienced declining centrality and growing dependence on hub-mediated connections.

This finding is particularly relevant because it links dependency to peripherality. Ports with higher hub dependency tend to display lower levels of closeness centrality, eigenvector centrality and node degree, indicating a more peripheral position within the network. Conversely, ports capable of generating larger traffic volumes and attracting direct services tend to show lower dependency on external hubs. The analysis therefore confirms that hub dependency is not merely an operational feature of container shipping; it is also a structural condition that shapes the ability of ports to access wider maritime networks autonomously. In periods of crisis, this condition becomes a potential source of vulnerability, because dependent ports have fewer alternatives when hub connections or carrier strategies change.

The third chapter extended this interpretation to the global scale, showing that maritime connectivity is highly uneven among countries. China emerges as the core country of the entire network and the countries located along the main East-West corridors, especially in the Northern Hemisphere, tend to show more diversified services, a greater number of operators, higher deployed capacity and fewer transhipment requirements. By contrast, small island states, countries in the Southern Hemisphere and countries located outside the main liner shipping corridors often depend on a limited number of services and carriers, and require longer transhipment chains to access the global network. It has also been noted that, in the Northern Hemisphere, certain countries are more central to the network, whilst at the same time exhibiting greater polarisation in relation to their neighbouring countries.

The Hormuz blockage scenario, although it took into account a geographical factor that had not been directly analysed among the clustering variables, appears to confirm, at least in part, the usefulness of this framework. This blockade appears to have had a limited impact on the overall connectivity of scheduled services. The greatest impact is, of course, evident in the Persian Gulf countries, which were already classified within the peripheral and vulnerable clusters. Countries that have shown greater resilience, such as Saudi Arabia and the United Arab Emirates, are also classified among the least vulnerable clusters. This suggests that the network of countries that are highly integrated in terms of global services already incorporates, to some extent, potential responses to factors of vulnerability. However, Scenario 2 shows that certain geographical conditions are an unavoidable factor of vulnerability for some countries.

Overall, the thesis contributes to the literature on maritime transport geography, port competition and network vulnerability in three main ways. First, it proposes a multi-scalar reading of container shipping vulnerability, connecting local port dynamics, regional hub-and-spoke structures and global country-level connectivity. Second, it shows that peripherality and dependency are distinct but interrelated dimensions of vulnerability. A port or country may be peripheral because it is geographically distant from main routes, topologically distant in terms of transhipment chains, or commercially marginal within carrier networks. It may be dependent because it relies on a small number of hubs, operators or services. When these conditions overlap, vulnerability increases. Third, the thesis highlights the role of shipping companies and alliances as key actors in the production of maritime vulnerability. Their decisions regarding service design, vessel deployment, port selection and route restructuring shape the geography of connectivity and determine which ports and countries gain or lose during periods of disruption.

Methodologically, the thesis draws on a wide range of data sources, including port calls, data from Lloyd's List, and liner service rotations published by carriers. This has enabled the author to examine the global maritime network and specific local changes at individual ports at different scales and with varying levels of detail. From a methodological perspective, too, a granular empirical analysis, shift-to-share analysis, measures derived from complex network analysis, and k-means clustering of the components obtained from PCA have provided a wide range of tools for analysing the vulnerability of maritime transport from various angles. The findings did indeed provide useful insights into issues of peripherality, dependency and vulnerability.

The thesis also has some limitations. The analysis relies on available data on port calls, services, vessel capacity and operators, which provide a detailed representation of liner shipping connectivity but cannot fully capture all contractual, commercial and logistical dimensions behind carriers' decisions. Moreover, some of the analysed crises were still ongoing or recent at the time of writing, meaning that their long-term consequences could not be fully assessed.

Furthermore, in the final chapter, due to data limitations, it was not possible to assess the relative importance of the various carriers in the different liner services operated in alliance or in collaboration with other carriers, as determined by the cargo capacity deployed on the routes. Another limitation, which nevertheless leaves scope for further analysis, is the fact that the classification of countries did not take into account their size, the length of their coastline, the number of ports, or the different regional configurations within the countries themselves. Furthermore, various characteristics such as demographics, economic conditions and port infrastructure were not taken into account. A study examining these aspects in greater depth, and relating them to a country's maritime connectivity structure, could offer further insights into interpreting the results obtained so far.

Finally, examining changes in the structure of the container shipping network over the medium to long term would provide an understanding of how internal market restructuring processes, such as horizontal integration between carriers, or events linked to crises of various kinds, whether economic, geopolitical or environmental, have affected countries' connectivity at a global level.

Future research could also integrate freight-rate data and supply-chain cost indicators or examine the interaction between maritime connectivity and inland logistics networks. Further work could also compare the vulnerability of container shipping with other maritime sectors, such as energy transport or bulk shipping services. Furthermore, considering these findings, further exploration of the role of individual carriers and alliances could be undertaken in order to fully understand the extent to which individual players influence levels of vulnerability and dependence.

From a policy perspective, the results suggest that improving maritime resilience requires more than infrastructure investment alone. Port authorities and policymakers should pay attention to the structure of maritime services, the diversity of carriers, the degree of dependence on specific hubs and the availability of alternative regional connections. For gateway ports, strengthening hinterland integration remains essential, but it should be accompanied by strategies aimed at maintaining diversified maritime connectivity. For more peripheral ports and countries, reducing vulnerability may require policies that support service redundancy, regional cooperation and the development of alternative routing options. At the same time, the concentration of decision-making power in a limited number of global carriers raises important questions about the governance of maritime connectivity, especially for countries and regions whose access to global trade depends on commercially driven network configurations. From this perspective, projects such as China's 'Maritime Silk Road' or India's recent attempts to develop its own shipping company capable of competing on a global scale can be seen as factors that may, and, in the case of the Belt and Road Initiative, have already to some extent, alter the current structure of maritime transport.

In conclusion, this thesis not only provides an overview of certain conditions relating to the structure of global container shipping services at various scales, but also offers some interpretative frameworks that open up further avenues for analysis and research within the fields of geography and maritime economics on topics such as equitable access to international trade and the factors influencing levels of unequal development at the global level.

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# 6. Annex

*Table 26 Variable absolute value of countries and territories ISO 3166 Alpha-3 classification*

| ISO 3166-1 alpha-3 | N° of services - Interocean | N° of operators - Interocean | Annual cargo capacity - Interocean | N° of services - Extra regional | N° of operators - Extra regional | Annual cargo capacity - Extra regional | N° of services - Regional | N° of operators - Regional | Annual cargo capacity - Regional | N° of country directly connected | N° of country 1 transhipment | N° of country 2 transhipment | N° of country more than 3 transhipment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ABW** | 0 | 0 | 0 | 2 | 2 | 112201 | 0 | 0 | 0 | 6 | 56 | 78 | 13 |
| **AGO** | 3 | 5 | 788375 | 2 | 2 | 275494 | 4 | 3 | 511768 | 28 | 87 | 38 | 0 |
| **ALB** | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 299450 | 4 | 58 | 81 | 10 |
| **ANT** | 0 | 0 | 0 | 2 | 2 | 112201 | 0 | 0 | 0 | 6 | 56 | 78 | 13 |
| **ARE** | 20 | 19 | 9215746 | 42 | 17 | 6797356 | 0 | 0 | 0 | 47 | 78 | 28 | 0 |
| **ARG** | 1 | 1 | 35192 | 0 | 0 | 0 | 4 | 3 | 534929 | 6 | 72 | 67 | 8 |
| **ASM** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 23903 | 6 | 14 | 76 | 57 |
| **ATG** | 0 | 0 | 0 | 1 | 1 | 66674 | 0 | 0 | 0 | 6 | 50 | 77 | 20 |
| **AUS** | 27 | 13 | 18420839 | 0 | 0 | 0 | 2 | 2 | 614694 | 31 | 104 | 18 | 0 |
| **BEL** | 42 | 10 | 21088647 | 22 | 8 | 4766396 | 27 | 7 | 2181692 | 80 | 65 | 8 | 0 |
| **BEN** | 6 | 6 | 1199708 | 7 | 5 | 1361040 | 3 | 2 | 353351 | 29 | 102 | 22 | 0 |
| **BGD** | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 11 | 1929200 | 11 | 75 | 60 | 7 |
| **BGR** | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 5 | 551412 | 10 | 72 | 63 | 8 |
| **BHR** | 3 | 7 | 960625 | 4 | 4 | 462107 | 0 | 0 | 0 | 15 | 74 | 57 | 7 |
| **BHS** | 9 | 2 | 3259341 | 6 | 2 | 783287 | 0 | 0 | 0 | 39 | 99 | 15 | 0 |
| **BLM** | 0 | 0 | 0 | 1 | 1 | 6360 | 0 | 0 | 0 | 5 | 29 | 86 | 33 |
| **BLZ** | 0 | 0 | 0 | 1 | 1 | 65667 | 0 | 0 | 0 | 2 | 48 | 90 | 13 |
| **BRA** | 18 | 11 | 30644494 | 8 | 7 | 8853491 | 5 | 4 | 1119784 | 39 | 97 | 17 | 0 |
| **BRB** | 0 | 0 | 0 | 3 | 2 | 183221 | 0 | 0 | 0 | 11 | 54 | 71 | 17 |
| **BRN** | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 326056 | 6 | 76 | 64 | 7 |
| **CAN** | 27 | 11 | 10517320 | 3 | 3 | 695837 | 0 | 0 | 0 | 36 | 104 | 13 | 0 |
| **CHL** | 7 | 6 | 6757659 | 0 | 0 | 0 | 9 | 5 | 2224410 | 20 | 100 | 33 | 0 |
| **CHN** | 180 | 28 | 2,55E+08 | 27 | 22 | 23401037 | 303 | 22 | 91140019 | 79 | 67 | 7 | 0 |
| **CIV** | 9 | 6 | 4390997 | 11 | 6 | 2511670 | 8 | 2 | 1112841 | 36 | 87 | 30 | 0 |
| **CMR** | 4 | 5 | 1687361 | 4 | 3 | 728273 | 7 | 6 | 767758 | 32 | 89 | 32 | 0 |
| **COD** | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 302683 | 6 | 28 | 87 | 32 |
| **COG** | 5 | 5 | 1803007 | 3 | 4 | 416103 | 8 | 5 | 386741 | 30 | 90 | 33 | 0 |
| **COK** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 47806 | 6 | 14 | 76 | 57 |
| **COL** | 23 | 12 | 10257567 | 29 | 9 | 4736875 | 4 | 4 | 489243 | 54 | 82 | 17 | 0 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **COM** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 29627 | 1 | 22 | 94 | 36 |
| **CPV** | 0 | 0 | 0 | 1 | 1 | 30157 | 0 | 0 | 0 | 4 | 64 | 75 | 10 |
| **CRI** | 5 | 4 | 1390932 | 5 | 5 | 668171 | 3 | 5 | 310633 | 25 | 92 | 36 | 0 |
| **CUB** | 0 | 0 | 0 | 2 | 2 | 279734 | 0 | 0 | 0 | 3 | 59 | 78 | 13 |
| **CYP** | 0 | 0 | 0 | 2 | 2 | 514471 | 9 | 5 | 673895 | 18 | 79 | 51 | 5 |
| **DEU** | 46 | 10 | 30374512 | 14 | 8 | 3743231 | 31 | 9 | 4223623 | 73 | 67 | 13 | 0 |
| **DJI** | 2 | 2 | 652907 | 7 | 4 | 436508 | 0 | 0 | 0 | 13 | 76 | 57 | 7 |
| **DMA** | 0 | 0 | 0 | 1 | 1 | 36623 | 0 | 0 | 0 | 4 | 23 | 93 | 33 |
| **DNK** | 2 | 3 | 1732252 | 1 | 1 | 30634 | 9 | 6 | 1044895 | 23 | 90 | 40 | 0 |
| **DOM** | 7 | 5 | 3321245 | 12 | 9 | 1893478 | 0 | 0 | 0 | 38 | 95 | 20 | 0 |
| **DZA** | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 5 | 1358973 | 13 | 73 | 59 | 8 |
| **ECU** | 11 | 11 | 4613014 | 2 | 4 | 224402 | 6 | 4 | 972073 | 33 | 97 | 23 | 0 |
| **EGY** | 23 | 17 | 10103549 | 14 | 13 | 3611685 | 30 | 9 | 3449028 | 45 | 89 | 19 | 0 |
| **ERI** | 0 | 0 | 0 | 1 | 1 | 64077 | 0 | 0 | 0 | 4 | 28 | 88 | 33 |
| **ESP** | 45 | 11 | 34172068 | 40 | 9 | 7551334 | 36 | 9 | 4997529 | 89 | 59 | 5 | 0 |
| **EST** | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 5 | 476046 | 11 | 74 | 63 | 5 |
| **FIN** | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 1871112 | 10 | 75 | 63 | 5 |
| **FJI** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 288214 | 8 | 28 | 99 | 18 |
| **FRA** | 30 | 8 | 16634898 | 15 | 6 | 3660286 | 24 | 6 | 2007269 | 80 | 65 | 8 | 0 |
| **GAB** | 0 | 0 | 0 | 1 | 1 | 53265 | 4 | 4 | 381759 | 16 | 73 | 59 | 5 |
| **GBR** | 45 | 10 | 24940687 | 19 | 9 | 4416384 | 18 | 5 | 1673104 | 74 | 74 | 5 | 0 |
| **GEO** | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 3 | 380434 | 9 | 73 | 63 | 8 |
| **GHA** | 10 | 7 | 4396350 | 11 | 7 | 2454271 | 5 | 2 | 666687 | 38 | 94 | 21 | 0 |
| **GIN** | 0 | 0 | 0 | 6 | 6 | 521838 | 1 | 1 | 145326 | 18 | 79 | 51 | 5 |
| **GLP** | 2 | 1 | 683859 | 3 | 1 | 136316 | 0 | 0 | 0 | 23 | 94 | 31 | 5 |
| **GNB** | 0 | 0 | 0 | 2 | 2 | 85595 | 0 | 0 | 0 | 4 | 64 | 75 | 10 |
| **GNQ** | 0 | 0 | 0 | 2 | 2 | 401210 | 2 | 2 | 123596 | 18 | 79 | 51 | 5 |
| **GRC** | 8 | 8 | 4033565 | 6 | 6 | 1672468 | 32 | 9 | 3405833 | 45 | 90 | 18 | 0 |
| **GRD** | 0 | 0 | 0 | 1 | 1 | 45792 | 0 | 0 | 0 | 4 | 17 | 80 | 52 |
| **GTM** | 3 | 8 | 1567528 | 9 | 6 | 1063392 | 5 | 6 | 690431 | 21 | 83 | 49 | 0 |
| **GUF** | 1 | 1 | 117607 | 1 | 1 | 36040 | 0 | 0 | 0 | 9 | 87 | 50 | 7 |
| **GUM** | 1 | 1 | 178928 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 76 | 67 | 7 |
| **GUY** | 0 | 0 | 0 | 5 | 4 | 302630 | 0 | 0 | 0 | 12 | 56 | 72 | 13 |
| **HKG** | 33 | 11 | 13965553 | 6 | 10 | 1647876 | 79 | 14 | 8479682 | 45 | 93 | 15 | 0 |
| **HND** | 0 | 0 | 0 | 9 | 6 | 875613 | 2 | 3 | 248252 | 14 | 64 | 72 | 3 |
| **HRV** | 3 | 6 | 1567740 | 0 | 0 | 0 | 5 | 5 | 525389 | 15 | 87 | 48 | 3 |
| **HTI** | 0 | 0 | 0 | 4 | 4 | 302577 | 0 | 0 | 0 | 7 | 58 | 75 | 13 |
| **IDN** | 2 | 2 | 428240 | 2 | 5 | 649462 | 52 | 18 | 10956160 | 14 | 74 | 58 | 7 |
| **IND** | 29 | 14 | 20784957 | 73 | 22 | 27139127 | 13 | 5 | 2321771 | 62 | 69 | 22 | 0 |
| **IRL** | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 3 | 395168 | 6 | 82 | 60 | 5 |
| **IRN** | 1 | 1 | 159000 | 3 | 1 | 107696 | 0 | 0 | 0 | 7 | 67 | 69 | 10 |
| **IRQ** | 3 | 4 | 509224 | 6 | 5 | 1113848 | 0 | 0 | 0 | 12 | 75 | 59 | 7 |
| **ISR** | 6 | 5 | 3822890 | 3 | 4 | 1061590 | 16 | 8 | 2204164 | 31 | 94 | 28 | 0 |
| **ITA** | 29 | 11 | 25594124 | 11 | 5 | 3318012 | 36 | 10 | 7977560 | 66 | 79 | 8 | 0 |
| **JAM** | 6 | 3 | 2397455 | 18 | 5 | 1967254 | 0 | 0 | 0 | 48 | 85 | 20 | 0 |
| **JOR** | 8 | 9 | 1619521 | 3 | 3 | 267332 | 0 | 0 | 0 | 17 | 98 | 35 | 3 |
| **JPN** | 20 | 10 | 10933900 | 1 | 1 | 156456 | 101 | 17 | 29302322 | 34 | 83 | 36 | 0 |
| **KEN** | 6 | 15 | 1641145 | 9 | 10 | 1010604 | 4 | 4 | 247775 | 18 | 72 | 56 | 7 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **KHM** | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 12 | 2074632 | 11 | 72 | 63 | 7 |
| **KOR** | 73 | 20 | 38253386 | 7 | 13 | 2106432 | 124 | 21 | 19752146 | 63 | 82 | 8 | 0 |
| **KWT** | 0 | 0 | 0 | 6 | 5 | 1202093 | 0 | 0 | 0 | 5 | 35 | 83 | 30 |
| **LBN** | 2 | 3 | 1986387 | 2 | 2 | 797968 | 11 | 3 | 821977 | 26 | 95 | 32 | 0 |
| **LBR** | 0 | 0 | 0 | 3 | 3 | 285299 | 2 | 2 | 207071 | 18 | 76 | 54 | 5 |
| **LBY** | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 599165 | 10 | 73 | 60 | 10 |
| **LCA** | 0 | 0 | 0 | 1 | 1 | 45792 | 0 | 0 | 0 | 4 | 17 | 80 | 52 |
| **LKA** | 29 | 12 | 13303795 | 29 | 17 | 5843038 | 10 | 4 | 1350546 | 61 | 78 | 14 | 0 |
| **LTU** | 2 | 1 | 1511878 | 1 | 1 | 88139 | 16 | 9 | 1400949 | 22 | 91 | 40 | 0 |
| **LVA** | 0 | 0 | 0 | 1 | 1 | 88139 | 8 | 6 | 597310 | 14 | 76 | 58 | 5 |
| **MAR** | 26 | 9 | 13111193 | 30 | 7 | 4318917 | 17 | 7 | 1961848 | 72 | 71 | 10 | 0 |
| **MDG** | 1 | 1 | 129214 | 3 | 3 | 341585 | 3 | 2 | 200764 | 9 | 69 | 66 | 9 |
| **MDV** | 0 | 0 | 0 | 1 | 1 | 48813 | 0 | 0 | 0 | 2 | 58 | 77 | 16 |
| **MEX** | 27 | 19 | 18810707 | 11 | 8 | 2402596 | 4 | 6 | 697215 | 44 | 94 | 15 | 0 |
| **MLT** | 6 | 4 | 2473616 | 2 | 1 | 556182 | 13 | 4 | 1051202 | 43 | 96 | 14 | 0 |
| **MMR** | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 | 639710 | 9 | 74 | 63 | 7 |
| **MOZ** | 2 | 3 | 820864 | 5 | 5 | 1047545 | 2 | 2 | 419230 | 13 | 68 | 64 | 8 |
| **MRT** | 0 | 0 | 0 | 7 | 5 | 635682 | 0 | 0 | 0 | 17 | 80 | 51 | 5 |
| **MTQ** | 2 | 1 | 683859 | 2 | 1 | 72663 | 0 | 0 | 0 | 20 | 96 | 32 | 5 |
| **MUS** | 5 | 4 | 1863639 | 4 | 3 | 594554 | 5 | 3 | 207283 | 26 | 92 | 35 | 0 |
| **MYS** | 50 | 19 | 23291751 | 31 | 19 | 7600412 | 84 | 16 | 15889029 | 65 | 77 | 11 | 0 |
| **MYT** | 0 | 0 | 0 | 1 | 1 | 93280 | 2 | 2 | 69748 | 5 | 55 | 77 | 16 |
| **NAM** | 4 | 5 | 1374025 | 0 | 0 | 0 | 2 | 2 | 193556 | 25 | 94 | 34 | 0 |
| **NCL** | 1 | 1 | 110240 | 0 | 0 | 0 | 1 | 1 | 120204 | 10 | 91 | 50 | 2 |
| **NGA** | 11 | 7 | 3498583 | 12 | 6 | 2182063 | 4 | 2 | 556606 | 35 | 97 | 21 | 0 |
| **NIC** | 0 | 0 | 0 | 2 | 3 | 308672 | 4 | 6 | 523322 | 8 | 43 | 94 | 8 |
| **NIU** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 23903 | 6 | 14 | 76 | 57 |
| **NLD** | 43 | 9 | 22746487 | 13 | 9 | 2669027 | 20 | 6 | 1067102 | 76 | 70 | 7 | 0 |
| **NOR** | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 576322 | 7 | 78 | 63 | 5 |
| **NZL** | 10 | 7 | 7857462 | 0 | 0 | 0 | 3 | 3 | 638597 | 25 | 98 | 30 | 0 |
| **OMN** | 8 | 8 | 4666491 | 18 | 8 | 2715561 | 0 | 0 | 0 | 26 | 97 | 30 | 0 |
| **PAK** | 7 | 8 | 2030907 | 21 | 20 | 6074065 | 0 | 0 | 0 | 30 | 95 | 28 | 0 |
| **PAN** | 28 | 9 | 16810328 | 26 | 9 | 4357978 | 15 | 6 | 1798343 | 55 | 91 | 7 | 0 |
| **PER** | 19 | 12 | 9137412 | 2 | 4 | 304485 | 10 | 5 | 1820285 | 32 | 97 | 24 | 0 |
| **PHL** | 16 | 11 | 7041474 | 5 | 7 | 1166477 | 55 | 18 | 9677217 | 37 | 91 | 25 | 0 |
| **PNG** | 1 | 1 | 92114 | 0 | 0 | 0 | 1 | 1 | 64077 | 5 | 79 | 62 | 7 |
| **POL** | 4 | 4 | 4157956 | 1 | 1 | 88139 | 17 | 7 | 1643583 | 22 | 94 | 37 | 0 |
| **PRI** | 0 | 0 | 0 | 8 | 7 | 711631 | 0 | 0 | 0 | 16 | 53 | 74 | 10 |
| **PRT** | 11 | 5 | 4350505 | 6 | 3 | 935238 | 13 | 6 | 1383512 | 50 | 80 | 23 | 0 |
| **PYF** | 3 | 4 | 435077 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 94 | 45 | 2 |
| **QAT** | 2 | 1 | 1088090 | 7 | 4 | 730976 | 0 | 0 | 0 | 15 | 88 | 47 | 3 |
| **REU** | 4 | 4 | 1273431 | 3 | 3 | 341585 | 2 | 1 | 30634 | 19 | 96 | 38 | 0 |
| **ROU** | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 640134 | 9 | 75 | 61 | 8 |
| **RUS** | 1 | 1 | 270671 | 1 | 1 | 88139 | 9 | 3 | 820122 | 26 | 88 | 39 | 0 |
| **SAU** | 24 | 19 | 7873521 | 14 | 12 | 1085228 | 0 | 0 | 0 | 38 | 84 | 28 | 3 |
| **SDN** | 0 | 0 | 0 | 3 | 3 | 155237 | 0 | 0 | 0 | 4 | 28 | 88 | 33 |
| **SEN** | 2 | 2 | 242263 | 13 | 6 | 1386321 | 2 | 2 | 331727 | 31 | 79 | 38 | 5 |
| **SGP** | 94 | 17 | 46302390 | 27 | 18 | 6857034 | 85 | 15 | 10801453 | 71 | 73 | 9 | 0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SLB** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 21359 | 2 | 51 | 76 | 24 |
| **SLE** | 0 | 0 | 0 | 4 | 4 | 463644 | 2 | 2 | 287896 | 15 | 73 | 57 | 8 |
| **SLV** | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 6 | 569697 | 7 | 36 | 96 | 14 |
| **SOM** | 0 | 0 | 0 | 9 | 6 | 528145 | 0 | 0 | 0 | 14 | 58 | 68 | 13 |
| **STP** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 15900 | 6 | 28 | 87 | 32 |
| **SUR** | 0 | 0 | 0 | 3 | 3 | 167692 | 0 | 0 | 0 | 10 | 53 | 77 | 13 |
| **SVN** | 3 | 6 | 1567740 | 0 | 0 | 0 | 11 | 7 | 1023165 | 16 | 87 | 47 | 3 |
| **SWE** | 3 | 6 | 2566578 | 1 | 1 | 30634 | 17 | 7 | 1627471 | 23 | 92 | 38 | 0 |
| **SXM** | 1 | 1 | 117607 | 2 | 1 | 73034 | 0 | 0 | 0 | 17 | 83 | 46 | 7 |
| **SYR** | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 599854 | 12 | 68 | 65 | 8 |
| **TGO** | 7 | 6 | 3474468 | 7 | 4 | 1463489 | 8 | 2 | 963858 | 36 | 86 | 31 | 0 |
| **THA** | 13 | 11 | 7025627 | 8 | 11 | 1221332 | 70 | 21 | 10285869 | 27 | 102 | 24 | 0 |
| **TON** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 47806 | 6 | 14 | 76 | 57 |
| **TTO** | 1 | 1 | 117607 | 8 | 6 | 685979 | 0 | 0 | 0 | 23 | 78 | 50 | 2 |
| **TUN** | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 303266 | 9 | 77 | 59 | 8 |
| **TUR** | 15 | 13 | 14548023 | 12 | 7 | 8502472 | 44 | 10 | 10957220 | 47 | 86 | 20 | 0 |
| **TWN** | 30 | 12 | 16643060 | 3 | 8 | 888333 | 72 | 16 | 14083266 | 43 | 96 | 14 | 0 |
| **TZA** | 5 | 14 | 1060371 | 9 | 10 | 726047 | 3 | 3 | 195623 | 18 | 70 | 58 | 7 |
| **UKR** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 45315 | 1 | 39 | 92 | 21 |
| **URY** | 7 | 10 | 2927614 | 4 | 5 | 1022158 | 3 | 1 | 164512 | 23 | 100 | 30 | 0 |
| **USA** | 100 | 17 | 1,01E+08 | 24 | 7 | 10019491 | 3 | 1 | 905028 | 62 | 88 | 3 | 0 |
| **VCT** | 0 | 0 | 0 | 1 | 1 | 45792 | 0 | 0 | 0 | 4 | 17 | 80 | 52 |
| **VEN** | 0 | 0 | 0 | 7 | 6 | 1270675 | 0 | 0 | 0 | 9 | 60 | 77 | 7 |
| **VGB** | 0 | 0 | 0 | 1 | 1 | 6360 | 0 | 0 | 0 | 5 | 29 | 86 | 33 |
| **VIR** | 0 | 0 | 0 | 1 | 1 | 12720 | 0 | 0 | 0 | 5 | 29 | 86 | 33 |
| **VNM** | 42 | 12 | 25951397 | 11 | 12 | 1598745 | 126 | 20 | 15703688 | 49 | 87 | 17 | 0 |
| **WSM** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 23903 | 6 | 14 | 76 | 57 |
| **YEM** | 0 | 0 | 0 | 5 | 4 | 300987 | 0 | 0 | 0 | 8 | 52 | 70 | 23 |
| **ZAF** | 12 | 10 | 6231687 | 4 | 5 | 2056347 | 5 | 3 | 924267 | 35 | 88 | 30 | 0 |

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