Sold to China: Container Traffic in the Port of Piraeus

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Abstract

This paper analyzes the effects of the acquisition of the Port of Piraeus by the Chinese shipping operator COSCO in July 2016 on the organization of container traffic in Europe. Using real-time container ship positions provided by vessel tracking systems between 2015 and 2019, we study the impact of the privatization of the Greek port on the traffic of Piraeus and competing ports by vessels of different operators, and specifically COSCO. We use a difference-in-differences approach. The number of calls by container ships to Piraeus increased following its privatization, but this increase in attractiveness corresponds essentially to ships operated by COSCO whose capacity exceeds 3,000 twenty-foot equivalent units, and in particular the largest of them. We do not identify any crowding out effect between operators in Piraeus: the use of Piraeus by the vessels of other operators remains relatively unchanged. The privatization of Piraeus seems to have imposed the Greek port as COSCO's transhipment hub for the European market without this being to the detriment of ports in any other particular European area.

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1 Introduction

When COSCO Shipping Lines bought a majority stake in the port of Piraeus in July 2016, what attracted attention was not so much the privatization of the port,[1] but the fact that the Chinese state-owned shipping company would from then on be the main decision maker in the planning, management and operation of the port authority of the largest Greek port (and 9^{th} in Europe at the time) as well as in all activities taking place in the majority of the container terminals of the port.

Over 80% of world trade is carried by sea and thus transits through ports, which makes their port terminal facilities essential nodes where traded goods are handled. Private actors have been involved in the ownership and management of terminals since the 1990s,[2] however the full privatizations of port infrastructure were, and still are, an unusual configuration in the port industry, with few examples in the United Kingdom, in Australia and now in Greece. Also, the circumstances of the privatization that took place in the port of Piraeus in the summer 2016 are exceptional. There are three reasons to this. First, the new owner is the parent company of COSCO Shipping Lines, an international container transportation and shipping company, ranked fourth among the world's largest shipping companies in terms of fleet capacity. Second, the new owner is a state-owned enterprise, which is the merged entity of two separate state-owned shipping companies, China Ocean Shipping Company founded in 1961 and China Shipping Company created in 1997. Third, the new owner represents a country which is currently the first trade partner of the EU in terms of total trade, ranked first origin country for EU's imports and third destination for EU's exports. The essential function of a port being to manage the arrival and departure of imported and exported goods, this trio of facts has the potential to generate substantial changes in the organization of inbound and outbound container traffic in the port of Piraeus.

In this paper, we use real-time ship positions from vessel tracking systems to identify the ports where ships stop before and after July 2016 and thus determine whether the change in ownership of the Port Authority of Piraeus has affected the number and mix of ships arriving at that port, possibly at the expense of other European ports. Given the importance of COSCO and its proximity to the Chinese government, this development could signal a strategic reorganization of China's trade flows with Europe that would have significant consequences for the other operators using the Greek port and could also imply a reallocation of traffic to the detriment of other European ports.

[1] About 7% of European ports are partially or fully privatized in 2022 (Verhoeven, 2011). According to the previous edition of the European Seaport Organization, in 2011 4% of port authorities are privately-owned, among which 2% by industry, 1% by logistics companies and 1% by financial investors. In 2022, 1% of European ports are fully privately owned.

[2] Privatization emerged along several forms and contractual arrangements. Horizontal integration involves port operating companies expanding nationally or internationally, as in Zeebrugge, where APM Terminals, a Dutch logistics company, owned one of the three container terminals from 2004 to 2017. Vertical integration takes place when a shipping line becomes the terminal operator. It happened for this same terminal in Zeebrugge which was sold in 2017 to COSCO Shipping. Also, the Italian-Swiss shipping company MSC became the owner of the Normandie container terminal in the port of Le Havre in 2022, controlling two of the three container terminals in Le Havre. The third category are financial holdings which see terminals as assets with a future profitability. DP World is one of the leading investment funds active in container terminals.

We hence pay particular attention to the evolution of ships' arrivals by operator to disentangle the Chinese shipping line COSCO from other container carriers, reporting facts and analysis on three questions related to the consequences of the privatization of the port of Piraeus.

First, we want to understand how the privatization of the port authority of Piraeus affected the relative attractiveness of the port. We document how the size of the two container terminals which COSCO controlled since 2016 increased significantly from 2009 until the year 2019, which is also visible in the improvement of the port's position in international rankings. We provide a difference-in-differences estimate of how the evolution of the port in terms of number of port calls differs from the one of other comparable ports. We identify a clear upward path for the port of Piraeus when compared to three different sets of port control groups: first the core European ports in our sample, second a sub-sample of these core ports limited to ports hosting more than 50 container ships per month, and last a group of 4 ports selected for their ability to reproduce the Piraeus port's traffic before its acquisition by COSCO (synthetic group method). We then zoom in on this evolution by untangling the ships by their operator and we highlight that the increase in the number of calls received by Piraeus comes from increased use of the port by ships operated by COSCO. While the number of calls by vessels operated by different carriers is increasing as the port's capacity expands, it is being overtaken by the fact that other ports are also experiencing moderate increases in traffic. In the end, the increase in the number of vessels stopping in Piraeus is shown to be significant and lasting only for COSCO ships. This outcome should be interpreted knowing that COSCO had been present in the port of Piraeus before the summer 2016 under a concession agreement over two container terminals since 2009, with limited decision possibilities. The 2016 privatization changed this equilibrium and gave more room to the company to organize the port and its terminals to optimize its objective as a shipping line and as a manager of a port.

Our second question uses the finest level of disaggregation at the ship level to study container traffic: we analyze whether ship calls in the port of Piraeus have increased or decreased in frequency after the privatization of the port authority. We pay particular attention to ship operators and estimate difference-in-differences equations on the evolution of port calls for each of the major shipping lines before and after the Chinese company became the main decision maker in the Piraeus port authority. We confirm that the container ships operated by COSCO show an increase in their use of Piraeus that can be quantified as a 5 percentage point increase in their probability of stopping in Piraeus after privatization. In addition, a portion of COSCO's vessels serve routes connecting Europe to Asia and thus can be used to transport goods manufactured in China. Controlling for the fact that the vessels served Asia during the sample period does not invalidate the results on Piraeus: COSCO vessels call at Piraeus more frequently, even after controlling for routes to China. We then disentangle the effect by vessel size, distinguishing three categories in terms of capacity: feeders under 3,000 TEUs, medium-sized vessels between 3,000 and 10,000 TEUs, and vessels over 10,000 TEUs. The increase in calls to Piraeus, previously observed on average for all vessels, appears to be due mainly to the behavior of medium and large container ships. This could be interpreted as COSCO creating a hub for its trade with Europe, with more large COSCO ships having Piraeus as an arrival point than before privatization. Medium-sized ships can also make more stops in the port to pick up cargo and deliver it to the next destination. Finally, the new hub role of the port of Piraeus has not so far been to the detriment of the port's use by other carriers: no crowding out of other lines is observed. Only the Taiwanese company Yang Ming (9^{th} in terms of fleet size in our data) shows a clear and significant decrease in its calls to Piraeus.

Our third question explores the spillover repercussions of COSCO's increased use of the Port of Piraeus. We seek to understand whether the 2016 privatization has led to an overall reconfiguration of COSCO ships' port choices in Europe. The question boils down to whether COSCO ships' stops in Piraeus complement or substitute for stops in other European ports. We study these possibilities in a framework where we compare the calls in Piraeus and in the other major European geographical areas (Mediterranean Sea, Atlantic shore and North Sea) with those in the Baltic Sea. For large container ships, there is indeed a negative correlation between these calls: the ships operated by COSCO in Piraeus show an increase in the number of calls in the port of Piraeus in parallel with a decrease in the number of calls by COSCO in the other European ports located in the Atlantic and Northern Europe. The magnitude of the increase observed in Piraeus is not matched by a symmetrical decrease in any European port. While it is possible that several Western European ports are losing traffic from COSCO vessels during the period when it is concentrated in the Greek port of Piraeus, there does not seem to be a complete substitution and the stops in Piraeus seem to be added to the Chinese operator's European shipping route.

Our analysis is based on maritime data which consists of information broadcast by ships indicating their position in real time. Ports collect this information, which is the modern version of logbooks detailing the arrivals and departures of ships from ports. We observe daily calls in all European ports for 2015-2019, which we supplement with ship-specific and port-specific information. We know the name, ID of the ship as well as its owner, operator, and technical information such as its dimensions (length, height and capacity). We leverage the geographical coordinates of berths to identify port calls.

Our paper is situated at the intersection of three literatures: the overall impacts of infrastructure improvements, the effect of privatization on port efficiency, and the analysis of maritime micro-data in the context of international trade.

First, the Chinese shipping company's investment in the port of Piraeus can undoubtedly be analyzed as an event that modernized and improved the overall capacity of the port, making it more likely to be chosen as a gateway to European markets by various shipping companies. The benefits of infrastructure investment have been studied on port choice in the US (measured by incoming shipments in the ports) by Blonigen and Wilson (2008). Seaport infrastructure development is shown to impact FDI (Blyde and Molina (2015) among others) as well as firm-level exports (Martincus and Blyde, 2013). Overall welfare gains have been identified (Allen and Arkolakis (2022) analyze the effects of a reduction in domestic congestion costs) and compared to corresponding costs (Ducruet et al., 2020). We contribute to this literature by providing several facts showing how a change in the supply capacity of a southern European port, Piraeus, alters the equilibrium distribution of ships calling at different European market entry ports.

Second, there is a related literature analyzing the determinants of port efficiency. Transport infrastructure plays a crucial role in economic development, as it strongly impacts the cost of trade. The literature estimates that port efficiency is a key factor in transport costs (see for instance Blonigen and Wilson (2008) for an estimate using US data). Clark et al. (2004) shows that port efficiency is not only dependent on the physical infrastructure of the port, but it is also strongly influenced by port management rules and local business regulation. Djankov et al. (2010) also emphasizes the importance of port efficiency on trade. It finds that time is a crucial component of transport costs and that each additional day that a product is delayed prior to being shipped reduces trade by more than 1%. However, poor road or port infrastructure accounts for only about 25% of the delays and the majority of delays are caused by administrative formalities. An extensive review of the literature on port economics and competitiveness by Martínez Moya and Feo Valero (2017) shows that the role of the port authority is crucial in determining the competitiveness of ports which closely depends on the reliability of port services. This includes the implementation of measures such as full supply chain, cooperation between service operators, and terminal automation, which improve the effectiveness and efficiency of port operations. We add to this literature by evaluating the impact of privatizing port infrastructure on the relative attractiveness of the port in question.

Finally, our paper is part of a recent and growing literature that analyzes international trade from the perspective of microdata on the flow of goods transported by sea. This literature first developed by analyzing historical data from logbooks that recorded the arrivals and departures of ships in ports. These data are used in articles analyzing the impact of trade on development Pascali (2017), the impact of ship networks on trade (Marczinek et al., 2022; Gomtsyan, 2022), and the impact of maritime invention on trade and population distribution Miotto and Pascali (2022). Recent technological advances associated with the Automatic Identification System (AIS) make it possible to observe vessel movements at high spatio-temporal resolution and to address new questions. In an influential paper, Brancaccio et al. (2020) combines contracts between shipowners and exporters and detailed data on vessel movements to assess the role of endogenous trade costs on international trade. In a companion paper, Brancaccio et al. (2018) exploits vessel positions to investigate the role of fuel cost on world trade. These data are also used to measure the impact of transformation of the maritime network. For instance, Heiland et al. (2019) assesses the impact of the 2016 Panama Canal expansion on trade costs, and March et al. (2021) studies the reduction of maritime traffic caused by COVID-19. We contribute to this expanding literature by exploiting an untapped source of AIS data to analyze the organization of container traffic in Europe.

The paper is structured as follows. Section 2 provides background on the change of ownership of the Port of Piraeus. Section 3 then presents the maritime data we use as well as descriptive statistics on ships and ports. We devote Section 4 to exploring how the evolution of the number of ships calling in Piraeus compares to that in other European ports throughout the period. Section 5 contains the ship-level estimates on different operators, Section 6 asks whether COSCO changes its routes in other European ports, and Section 7 concludes.

2 The context

Throughout the paper we equivalently use the words *operator*, *carrier*, *shipping line* or *charterer* to refer to the company taking care of the transport of containers. Also, in the following we define container ships as those named *fully-cellular container ships* in the Lloyd's list.[3]. We now provide some elements of context for the arrival of the Chinese shipping line COSCO in the governance of the port of Piraeus.

2.1 Ports terminals concession and the role of port authority

The evolution of port governance between 1980 and 2000 was marked by a shift from the traditional model of public ownership of port entities providing all logistics and maintenance services to a series of possible forms of privatization, not only of terminals but also of parts of the ports (Slack and Frémont, 2005; Notteboom et al., 2021). The 'public-port authority-private terminal operator's model is today the main institutional structure governing ports in the world. The 1990s saw the involvement of private third parties at various stages of operations. European ports relied on concession contracts to have container handling within the terminals managed by one of three main types of companies: first, international logistics companies that were previously independent and largely local handlers and have expanded their operations to many parts of the world. Hutchinson Ports and PSA, the Port of Singapore Authority, are Asian examples (based in Hong Kong and Singapore), Eurogate is a European example and SSA is a U.S. example, all four of which are among the largest terminal operating companies.

Second, shipping lines have also become involved in terminal management, creating separate terminal management divisions or companies (Maersk and APM Terminals, or COSCO and PCT in Piraeus, CMA-CGM and Terminal Link) provide a number of examples.[4] Third, financial companies are also involved in terminal operations: investment banks, pension funds or sovereign wealth funds (DP World) have invested in terminals and manage them either directly or through the historical operator.

In all these cases of concession contracts signed for the operation and management of the terminals, whatever the amount of the operations and risks transferred to private parties, the assets remain public (Zhu et al., 2019; Farrell, 2012) and this represents the difference between devolution and privatization. The privatization of ports through the 'private ownership and private operations' model is an unusual configuration in the port industry. Two countries provide examples of port privatization that bear some similarity to that which took place in the Piraeus Port Authority. The United Kingdom fully privatized its ports in the early 1980s. As a result, private companies now

[3]This refers to 'Ship fitted throughout with fixed or portable cell guides for the carriage of containers' in the OECD transport statistics. In terms of cargo ships, this excludes ships that are fitted for both containers and vehicles and which might behave differently since they need facilities adapted for discharging both sets of goods (a very small minority of ships in our database, called 'container / Ro-Ro cargo ships' in the Lloyd's list)

[4]Refer to Drewry Shipping Consultants (2016). The major distinction between logistic firms and shipping lines running terminals is that in the former case, terminals are run on a multi-user basis (they handle cargo from different carriers) whereas shipping lines may organize the terminal's use to be either single (cargo from its own container fleet) or multi-user.

operate many of the country's ports and have been granted regulatory powers over them (Baird and Valentine, 2006). More recently, Australia has almost completely privatized its port assets: many port authorities are now owned by Canadian and Australian pension funds through 99-year leases (Meersman et al., 2014).

2.2 The port of Piraeus

We now turn to the specifics of the privatization process of the Piraeus port authority. We present the important changes that have affected its statutory regime and ownership structure, and briefly present the parallel evolution of the port's size, which has increased in container terminal capacity. Although the Chinese operator has been involved in terminal operations and infrastructure construction since 2009, it did not have extensive powers at the port authority until 2016.

The Piraeus Port Authority was state-appointed and state-controlled until 1999, when it was transformed into a publicly traded company, with the Greek state holding 75% of the shares and a majority stake in the management of the port authority (Psaraftis and Pallis, 2012). In 2001, the Greek government signed a concession agreement with the corporatized port authority, granting it the exclusive right to use and operate the port's facilities: at the time, the port included two container terminals (Terminals 1 and 2) and an area where a future Terminal 3 would be built. The state did not rule out the idea of future concessions that would include the private sector.[5] This idea was officially formalized in 2007 for Terminals 2 and 3. COSCO won the tender and signed an agreement for the development, operation and commercial use of the existing Terminal 2 and for the construction, operation and commercial use of Terminal 3. Terminal 1 remained operated by the Greek Port Authority.

Although this agreement is part of a concession ending in 2052 and has certain limitations (the government can terminate the concession under certain conditions, and the new owner cannot easily sell the asset), the only entity that is not transferred to COSCO is the land, which classifies this agreement as a master concession in which the concessionaire is allowed to reorganize or divide the port business.

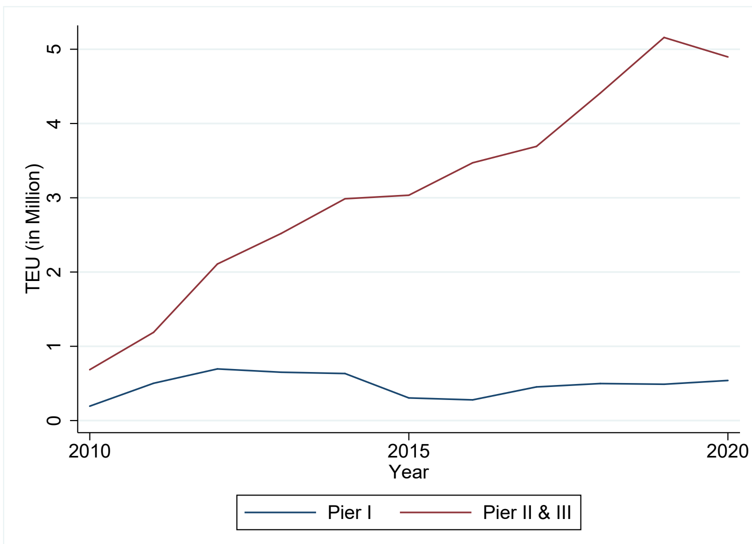
Until 2016, the relationship between the Port of Piraeus and COSCO was a typical one in the container terminal industry: COSCO was involved in terminal operations through a concession agreement, while the Port Authority remained independent and played a key role in the planning and development of port infrastructure and facilities. In 2014, the Greek government, through the Hellenic asset Development Fund (HRADF), proposed to sell 67% of the Piraeus port authority and launched an international tender. COSCO was the only company to submit a bid and acquired a majority stake (51% in the first phase) in the PPA, committing to €350 million of investment in the port over the next ten years (Pallis and Vaggelas, 2017). Although this agreement is part of a concession ending in 2052 and has certain limitations (the government can terminate the concession under certain conditions, and the new owner cannot easily sell the asset), the only entity that is not transferred to COSCO is the land, which classifies this agreement as a master concession in

[5] Refer to Psaraftis and Pallis (2012) for more details.

which the concessionaire is allowed to reorganize or divide the port business (Pallis and Vaggelas, 2017; World Bank, 2003).

The available statistics on the number of twenty-foot equivalent (TEU) containers and the gross tonnage handled suggest that Piraeus is becoming increasingly important.[6] Figure 1 shows the different evolution of capacities in Terminals II and III, the two container terminals managed by COSCO, and Terminal I, the container terminal managed by the Piraeus Port Authority. The capacity of Terminal I has evolved over the decade from one-tenth of a million TEUs to half a million TEUs. The capacity of Terminals II and III almost doubled between 2010 and 2011 (from 0.6 to 2.1 million TEUs) and tripled again between 2011 and 2016. The capacity of the two COSCO terminals continued to grow, reaching a maximum of 5.15 million TEUs in 2019.

Figure 1: Piraeus Port Yearly throughput 2010-2020



Source: Piraeus Port Authority

Appendix Table A-1 shows how the port of Piraeus evolved in the Eurostat ranking of European ports by gross tonnage. The port ranked 18^{th} in 2007 and has steadily moved up the list as it expands its capacity. In 2019, Piraeus ranks fifth in Europe and second in the Mediterranean. It is the European port that has seen its activity grow the most between 2007 and 2019: +365% in gross tonnage compared to, for example, Genoa, which is also growing by 165%.

Let us now detail the maritime microdata on which we rely for the rest of the paper, and highlight the evolution of the port of Piraeus in container vessels' choices of routes.

[6] Twenty-foot equivalent unit (abbreviated TEU) is based on the volume of a 20-foot-long (6.1 m) intermodal container, a standard-sized metal box which can be easily transferred between different modes of transportation, such as ships, trains, and trucks. Gross tonnage (GT) is a measure of the size of a vessel based on the volume of all enclosed spaces of the vessel.

3 Data and descriptive statistics

We begin by introducing the vessel tracking system that has recently allowed researchers to work on maritime issues using highly disaggregated data. We then explain the sources of our data and present details about the ship operators and ports we select for our empirical work.

3.1 AIS data and the port choice database

The safety regulation adopted by the International Maritime Organization (IMO) requires that all vessels above a certain size[7] transmit their position and movements by transceivers carried on board, through the AIS tracking system (Automated Identification System) that became effective and mandatory in December 2004. Because AIS tracks the position of cargo ships (among other things) in real time, researchers have been interested in using this data to address issues of international trade from a highly disaggregated micro perspective: the availability of AIS data replaces the old system of logbooks that recorded ship arrivals and departures in port. The literature relying on this detailed data, presented in the introduction, relies exclusively on datasets purchased from companies providing specialized AIS data solutions. Due to the high cost of the datasets, the existing papers rely on subsamples, limited to a geographic area or time subperiod,[8] of vessel positions based on port calls from April to October 2014.

In this paper, we rely on AIS data obtained from an online sharing system to which our university project contributes. While the obvious advantages are the low financial cost and the very long time period, our data has some disadvantages as it depends on the spatial coverage of the antennas of other contributors and the proper functioning of these. Real-time AIS data can be captured by any agent equipped with a receiver, including neighboring vessels, port authorities and satellites. Public or private organizations (among them maritime institutes, aerospace centers and universities, as in our case) can also install a receiver to contribute to the sharing of information they work with on a website called AISHub. Our data starts in April 2015 and records the daily positions of ships around ports, in the areas covered by AISHub contributors.

A comparison with Eurostat highlights that AISHub's data geographical coverage for Europe is excellent. To ensure that the results are representative, it is important to compare the geographic and temporal scope of our data with that of data typically obtained from established providers. Eurostat lists statistics about European ports[9], reporting a series of variables for each of them on a quarterly basis, two of which relate to maritime traffic: the number of ships and the gross tonnage of ships.

The left panel of Figure 2 reports the total number of vessels received by each port from both the Eurostat and AISHub databases. The values are obtained by selecting the 30 largest European ports, restricting to container ships, and summing the number of incoming vessels for each port

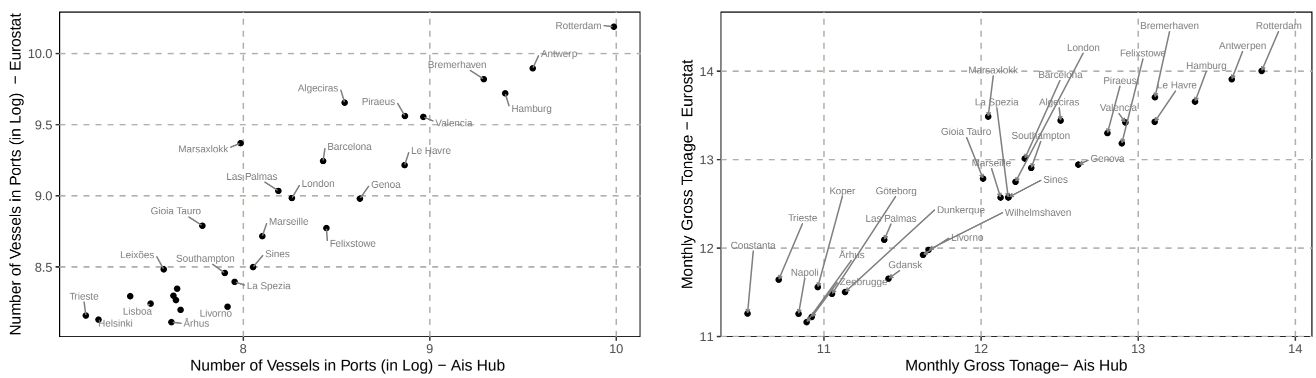
[7] All ships above 300 gross tonnage engaged on international voyages, cargo ships above 500 gross tonnage not engaged in international voyages, all passengers ships irrespective of size.

[8] Heiland et al. (2019) use satellite and port calls data for the calendar year 2016 (Ganapati et al., 2021).

[9] The database's name is MAR_TF_QM and is accessible at `https://ec.europa.eu/eurostat/databrowser/view/MAR_TF_QM__custom_3760994/default/table`.

for the period July 2015-December 2019. The right panel of Figure 2 focuses on the gross tonnage handled in each port from the two databases respectively. The correlation between the Eurostat and AISHub figures in the two panels is 0.93 and 0.94 respectively.

Figure 2: Number of vessels and gross tonnage in ports (in log) - Eurostat vs AIS Hub



<u>Note:</u> Authors' computation using Eurostat and AISHub data. Eurostat data report, by port, the quarterly number of incoming vessels and the gross tonnage. Both are restricted to container vessels and to the 30 largest European ports, and summed across all quarters between July 2015 and December 2019. AISHub data report the daily number of port calls by port and (after merging with the Lloyd's list to add ship-specific data) the gross-tonnage fo each incoming vessel. Both variables are also restricted to container vessels and to the 30 largest European ports, and summed throughout the period 2015-2019.

Since the system generates a massive amount of data (signal frequency increases with ship speed), the resulting database provides very granular observations that need to be cleaned. The basic cleaning of our database consists of getting rid of duplicate data over short periods of time (multiple occurrences of a given vessel in a given port in a given day), as well as removing periods where our antenna did not work properly. Since our focus is on European ports, we limit our call data to European ports. We then merge the AIS port calls with ship-specific variables from the Lloyd's list, namely ship name, ship type and carrier name. This allows us to select container ships from the 192 detailed ship categories.

3.2 Container ships and operators

The Lloyd's List reports around 6,000 container ships in service around the world in 2015. About 5,000 of these are observed in motion in our data in 2015, including about 2,400 in Europe. Table 1 lists the 16 companies which operate more than 20 vessels that call in European ports in our database, ranked by the number of chartered ships. COSCO is the sixth largest operator overall, but the second largest in Piraeus, where it accounts for 17% of calls. This highlights two interesting points. First, there is a diversity of companies calling at Piraeus, and second, the relative role of the different operators differs considerably between ports. We will consider the four main shipping lines (MSC, Maersk, CMA-CGM and Hapag-Lloyd) in our empirical approach to identify those that may have suffered crowding out when COSCO increased its presence in the port of Piraeus.

Container ship capacity is measured in twenty-foot equivalent units (TEU). Container ships are distinguished into feeders (below 3,000 TEUs) and bigger vessels that engage in longer trips.

Feeders typically collect shipping containers from different ports and transport them to central container terminals where they are loaded to bigger vessels, or for further transport into the hub port's hinterland. Within the large boats we can distinguish between Panamax and Post Panamax (capacity between 3,000 and 10,000 TEUs) and New Panamax (or Neopanamax) starting at 10,000 TEUs.[10] COSCO stands out for the relatively low share of feeders (14% compared to 23% for MSC and 30% for Maersk) in its fleet present in Europe, which suggests that some of the goods brought in on huge COSCO vessels from China are unloaded and then transported by other European operators on smaller vessels to their final location. The rise of COSCO's operations in Europe would hence possibly trigger complementarity effects (and not just competition effects) for European operators.

Table 1: Main operators in European ports (2015-2019)

Operator	Country	Number of ships	Share in %	Share by capacity (TEU) in %		Operator share in number of port calls (in %)	
				3,000-10,000	≥ 10,000	Europe	Piraeus
MSC Mediterranean Shipping	Italy-Switz.	458	18	54	23	22.7	19.5
Maersk	Denmark	384	15	47	22	17.3	4.2
CMA CGM SA The French Line	France	246	10	42	17	11.5	8.2
Hapag-Lloyd	Germany	209	8	55	22	10.9	6.6
COSCO Shipping Lines	China	156	6	42	44	4.7	17.6
Ocean Network Express	Japan	114	4	58	33	4.4	5.9
Evergreen Marine Corp	Taiwan	90	4	54	37	2.3	9.6
APL LLC	US-France	59	2	54	44	2.1	0.9
Yang Ming Marine Transport	Taiwan	47	2	40	45	1.7	7.5
X-Press Feeders	Singapore	45	2	11	0	1.7	0.4
Orient Overseas Container Line	Hong Kong	43	2	51	37	1.7	0.6
Unifeeder	Denmark	38	1	0	0	1.5	0.1
Zim Integrated Shipping	Israel	35	1	69	3	1.2	4.7
Hamburg Sudamerikanische	Germany	35	1	94	0	1.3	0.2
Arkas Denizcilik ve Nakliyat	Turkey	30	1	3	0	1.1	5.6
HMM	South Korea	28	1	61	39	0.5	0.6
Cumulated Total		2017	79	49	25	86.7	92.1

Note:: Authors' computations based on fully-cellular ships calling in the European ports covered in our AIS data. Operators are identified using the Lloyd's list and are restricted to those with more than 20 container ships during the 2015-2019 period.

3.3 Ports

The facts and analysis we present in the following sections focus on a subset of the 181 ports we observe in Europe in order to improve comparability with the port of Piraeus. The European Commission identifies maritime ports within the Trans-European Transport network (TEN-T), and among those, 83 core ports. Insofar as we seek to analyze the trajectory of the port of Piraeus by comparing it to relatively comparable ports, we restrict our attention to those ports that are part of the Core network and that provide consistent temporal coverage in our database. We obtain a sample of 65 ports (including Piraeus). Table 2 lists the 33 ports (among which Piraeus) that receive more than 50 monthly port calls over the period, ranked by the average monthly visits received over July 2015-December 2019. Eleven European ports receive more than 100 container

[10] The largest category, the Ultra Large Container Vessel (ULCV) have a capacity of 14,501 TEUs and higher.

ship calls each month. Most of them are located in the North Sea, the Mediterranean Sea and on the Atlantic coast. The Port of Piraeus is ranked sixth with an average monthly number of calls equal to 177 for the period 2015-2019, this average is pulled up by the most recent years: the figure has increased from 130 calls per month in 2015 to 190 in 2019. The ranking of Piraeus presented in Table 2 is also consistent with the Eurostat ranking by gross tonnage for 2019 shown in Table A-1.

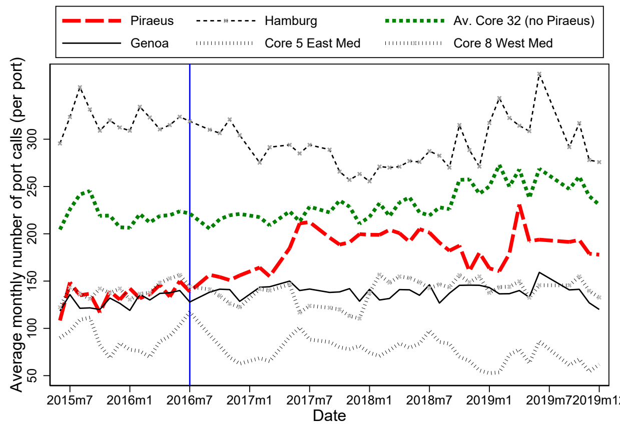
Table 2: European Core Ports with more than 50 monthly port calls

	Port Name	Country	Zone	Av. monthly visits	Share of COSCO ship (%)	Av. TEU	Ships by capacity (in %) 1,000 TEUs		Port calls share from ships	
							3-10	≥10	exited Europe	went to China
1	Rotterdam	Netherlands	NorthSea	538	6	4 236	42	26	61	30
2	Antwerp	Belgium	NorthSea	348	5	5 312	46	25	80	32
3	Hamburg	Germany	NorthSea	303	7	4 956	40	31	62	33
4	Bremerhaven	Germany	NorthSea	269	5	4 309	50	14	63	25
5	Valencia	Spain	Med	208	3	5 043	46	19	95	32
	Piraeus	Greece	Med	177	16	4 865	41	24	90	36
6	Le Havre	France	Atlantic	176	2	6 423	53	27	89	42
7	Algeciras	Spain	Med	173	2	5 265	42	14	97	27
8	Genoa	Italy	Med	139	8	4 881	46	21	95	33
9	Felixstowe	UK	Atlantic	119	8	8 192	42	38	81	47
10	Barcelona	Spain	Med	118	2	4 674	42	19	97	32
11	Marsaxlokk	Malta	Med	103	5	5 672	41	21	93	42
12	London	UK	Atlantic	98	1	4 951	52	14	82	34
13	Marseille	France	Med	90	8	5 240	47	20	97	39
14	Sines	Portugal	Atlantic	82	0	5 745	61	21	90	34
15	La Spezia	Italy	Med	76	7	6 244	42	26	96	44
16	Gdynia	Poland	Baltic	71	5	1 526	31	0	23	4
17	Livorno	Italy	Med	70	3	3 770	58	0	93	24
18	Southampton	UK	Atlantic	68	3	8 019	41	37	85	60
19	Venice	Italy	Med	68	10	1 725	22	0	88	12
20	Gioia Tauro	Italy	Med	66	0	6 357	55	23	91	40
21	Moerdijk	Netherlands	NorthSea	58	0	585	0	0	15	0
22	Aarhus	Denmark	Baltic	57	3	2 496	3	22	29	13
23	Ambarli	Turkey	Med	55	4	3 963	39	7	80	29
24	Lisbon	Portugal	Atlantic	55	2	1 726	29	0	74	9
25	Gothenburg	Sweden	Baltic	55	6	2 919	4	28	37	20
26	Liverpool	UK	Atlantic	54	0	1 483	30	0	51	7
27	Mersin	Turkey	Med	54	6	4 125	37	8	100	29
28	Kotka	Finland	Baltic	53	13	1 440	4	0	26	4
29	Helsinki	Finland	Baltic	53	9	1 190	2	0	24	6
30	Gdansk	Poland	Baltic	52	16	5 385	14	33	60	37
31	Koper	Slovenia	Med	51	14	3 624	20	21	94	32
32	Wilhelmshaven	Germany	NorthSea	51	8	7 113	27	33	68	38

Note: Authors' computations using AIS data on fully cellular containers between June 2015 and December 2019. The table covers 32 ports + Piraeus, which are "core" ports, i.e. on the core network identified by Trans-European Transport Network and which receive more than 50 monthly port calls over the period. Average TEU is the average capacity in TEU of vessels calling in those ports.

Let us now explore with the raw data the respective evolution of the ports over the months. Figure 3 displays the monthly number of port calls per port, for six different sets of ports during our sample period. The average monthly number of port calls in the 32 core ports listed in Table 2) rose from an average of 200 port calls by container ships in July 2015 to 245 at the end of 2019. The port of Piraeus, shown in the bold dashed line, begins at a relatively low level in July 2015 at around 130 port calls per month. The figure increases quite sharply towards the beginning of 2017 as it gains about 60 monthly port calls and remains at this average level of 190 monthly stops until the end of the sample in 2019.

Figure 3: Evolution of number of port calls in Europe



Source: Authors' computations using fully cellular containers covered in AIS data. Core 32 denotes the 32 European "core" ports (other than Piraeus) which receive more than 50 monthly port calls over the period as listed in Table 2. Genoa and Hamburg are the two ports identified as the most similar to Piraeus in terms of pre-privatization characteristics using the synthetic control methodology (Abadie and L'Hour, 2021). Core West Med includes Algeciras, Barcelona, Genoa, Gioia Tauro, La Spezia, Livorno, Marseille, Valencia. Core East Med includes Ambarli, Koper, Marsaxlokk, Mersin and Venice.

Two other single ports are displayed on the figure as they are identified in the section as ports that are highly comparable to the port of Piraeus: Genoa in northern Italy on the Mediterranean sea and Hamburg in northern Germany on the Baltic sea. The latter appears on the upper side of Figure 3 as it receives on average 300 port calls per month throughout the period and it is the third port in Europe. Its evolution appears more irregular than the ones reported for other ports. Finally, the port of Genoa is very similar in size to the port of Piraeus in particular in 2015 and 2016, between 100 an 150 port calls per month on average. While the Piraeus denotes by jumping to a higher level from approximately the first third of the figure, Genoa is very stable with a slight increase throughout the period.[11] With these descriptive figures in mind, we now turn to the estimates to study the particularity of the evolution of calls for Piraeus, and its composition among ship operators.

[11] The port of Hamburg has four container terminals; the port of Genoa has three container terminals (a fourth has recently opened in 2020).

4 Relative attractivity of the Piraeus

To show whether the aggregate number of port calls evolves differently in Piraeus than in other European ports from the summer 2016 on, we estimate a simple difference-in differences equation on the number of port calls per port. Our sample corresponds to port calls in the 65 and 33 ports shown in Table 2, in each month from July 2016 to December 2019. We use a difference-in-differences methodology to investigate whether the port of Piraeus has seen an increase in traffic following its acquisition by COSCO in July 2016. Let us compute the number of times ships call in European ports in each month over the period. We investigate whether the count for Piraeus compared to other ports (first difference) has evolved differently after the acquisition compared to before (second difference). The port-level estimated equation is the following:

$$\text{Port Calls}_{pym} = \beta \ \text{Piraeus}_p \times \text{Post}_{ym} + \lambda_p + \mu_{ym} + \epsilon_{pym} \tag{1}$$

In Equation 1, the explained variable, Port calls$_{pym}$, is the count of ships calling in European port p in month m of year y. The comparison of traffic before/after the privatization of Piraeus is picked up by the interaction between the dummy denoting Piraeus and Post$_{ym}$ dummy, which equals 1 in each *year-month* from July 2016 onwards. Our identification strategy exploits the timing of privatization of the Piraeus port. While the decision made by COSCO to acquire the port of Piraeus is obviously not random and certainly reflects that the Chinese operator assessed a potential for profitability, the exact timing was rather exogenous given that the privatization process was decided in 2014 and took time months to be finalized. Our specification accounts for the facts that the port of Piraeus was already among the largest in Europe in June 2016 (it ranked 9^{th} in in terms of gross tonnage handled in 2016, see Appendix Table A-1), and for the fact that each port has an intrinsic potential, via individual port fixed effects. The key assumption is that in the absence of privatization, the relative attractiveness of Piraeus compared to other ports would have remained at the same level as it was before the acquisition by COSCO.

Estimating Equation 1 requires tackling two issues: selecting the right estimator and finding the appropriate control group. Regarding the estimator, a recent literature has shown that the Two-Way Fixed Effect estimator is problematic in the presence of heterogeneous[12] and dynamic treatment effects[13] (Borusyak et al., 2021; Callaway and Sant'Anna, 2021; Sun and Abraham, 2021). We hence use the new estimator by De Chaisemartin and d'Haultfoeuille (2020) that is robust to this configuration. Second, selecting a group of ports to which to compare the port of Piraeus is not straightforward as there could be various acceptable criteria. We select three possible solutions based on the size of ports: the port of Piraeus is compared to groups of core ports in

[12]The problem arises because the estimated β is a weighted average of group time-level average treatment effects, where the weights are unequal over groups and time, and may be negative (De Chaisemartin and d'Haultfoeuille, 2020)

[13]The concern is that potential outcomes do not only depend on their current treatment but also on their past treatments.

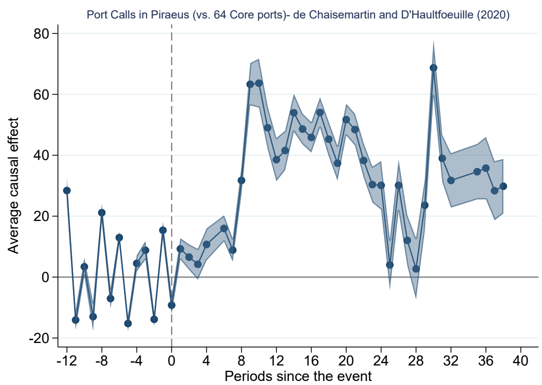
the European Commission TENT-T network (64 or 32), and then compared to more restricted groups chosen through the synthetic control group method. We begin by showing the estimated difference-in-differences coefficients obtained from the De Chaisemartin and d'Haultfoeuille (2020) estimator in Figure 4, using both the entire set of core ports and the version restricted to the 32 core ports which receive more than 50 port calls per month listed in Table 2.

The coefficients estimated by month are presented in Figure 4. The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO. The coefficients on the left of this line can be interpreted as the placebo tests of the parallel trends assumption. Panels (a) and (b) correspond to the total number of port calls from incoming ships whatever their operator. The increase in the number of calls is apparent in both panels, showing a bell shape over time: the Port of Piraeus experiences a larger increase in the number of calls than the other ports about 8-9 months after the change in ownership of the port authority, so in spring 2017. Subsequent developments are less clear, but the number of stops in Piraeus appears to remain at a higher level than before July 2016. Disentangling the aggregate rise in the number of port calls by operator of container ships leads to a clearer picture. Panels (c) and (d) reproduce the difference-in-differences estimates, only considering port calls by COSCO container ships, while non-COSCO operators are considered in Panels (e) and (f).

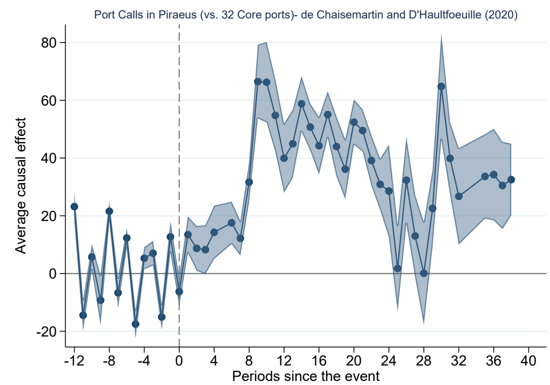
Panels (a) and (b) show that the number of calls by COSCO-chartered vessels begins to increase 8-9 months after the change in ownership (spring 2017): an average of 20 calls are added between 2015 and 2019. COSCO-vessels exhibit a coherent and steady increase throughout the period, highlighting that their number of stops in Piraeus rose significantly more than their number of stops in any other port of comparison. The evolution of the number of port calls for non-COSCO operated ships in Panels (e) and (f) exhibits only a temporary relative rise, i.e. a relative rise compared to other ports around 9 months from the change of ownership, which then dies out two years after 2016.

Figure 4: Port-level Difference in Difference (De Chaisemartin and d'Haultfoeuille (2020) estimator)

Total number of port calls : all operators

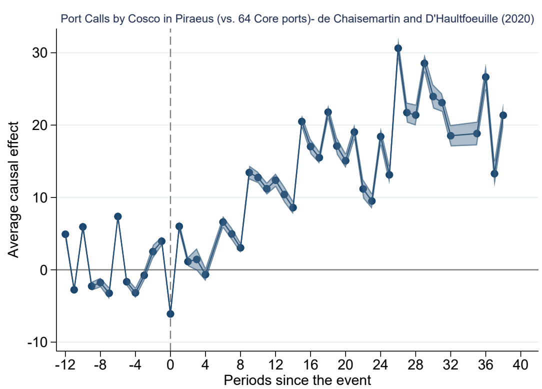


(a) Piraeus vs. 64 Core ports

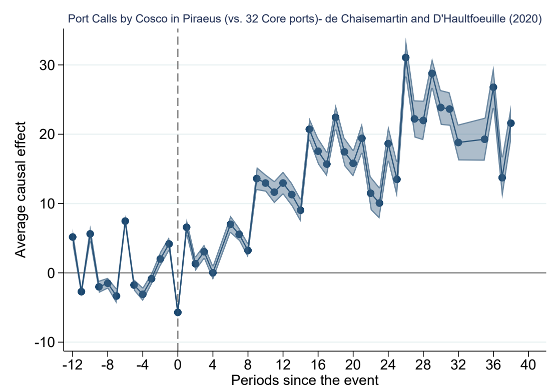


(b) Piraeus vs. 32 Core ports

Number of port calls by COSCO

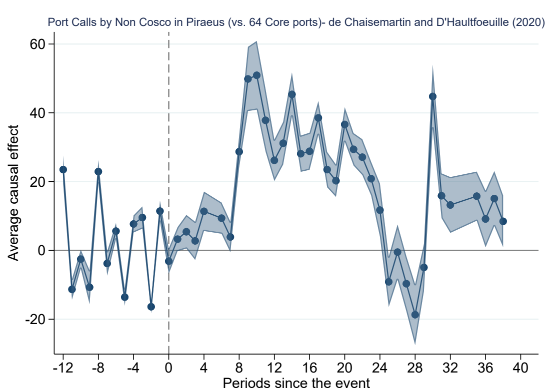


(c) Piraeus vs. 64 Core ports

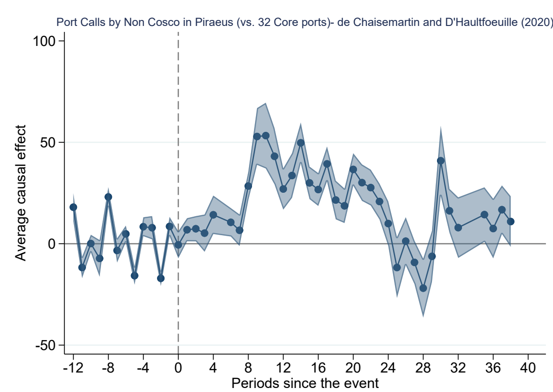


(d) Piraeus vs. 32 Core ports

Number of port calls by non-COSCO operators



(e) Piraeus vs. 64 Core ports



(f) Piraeus vs. 32 Core ports

Note: Figures generated by the *did_multiplegt* command (De Chaisemartin and d'Haultfoeuille, 2020). Standard errors are calculated using 100 bootstrap replications, clustered on the port level, 95% confidence intervals are shown. Figures plots the dynamic treatment effects as well as the placebo tests of the parallel trends assumption. In Panels (a), (c) and (e) the sample of ports includes the 65 European core ports (which includes Piraeus) with consistent data in our AIS. In Panels (b), (d) and (f), the sample includes Piraeus and the 32 core ports with more than 50 port calls per month listed in Table 2. The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

At this stage, our econometric issues do require some further solution which we now discuss. While pre-trends between treatment and control are not insignificant over the year before treatment (June 2015 to June 2016), the placebo estimators alternate in positive and negative around zero. Hence overall the results reported in all panels of Figure 4 provide only weak evidence of pre-trends. To further give us confidence in the absence pre-trends, we duplicate our results using a different control group for Piraeus. Namely, we use the synthetic control method to combine control units into one synthetic control unit to use as counterfactual to estimate the causal effect of the treatment (Abadie and Gardeazabal, 2003; Abadie and Imbens, 2011). We choose four matching variables: the first two are the quarterly number of port calls in total and by COSCO ships in each of the 4 quarters before Piraeus acquisition. The next two are the top decile of length and depth of the boats the ports welcomed in June 2016. The synthetic control unit that best replicates the pre-treatment evolution of the number of port calls consists of only 3 to 4 ports and differs slightly depending on whether we estimate coefficients for COSCO, non-COSCO, or the total number of port calls, as follows. It includes in all cases Genoa and Hamburg for at least three quarters of the total weight. Then the relatively small Finnish port of Kotka is added to the synthetic control unit to match the evolution of the number of port calls for COSCO ships in Piraeus before July 2016. On top of Genoa and Hamburg, the synthetic control unit for the number of port calls by non COSCO ships contains the Mediterranean ports of La Spezia and Marsaxlokk. Finally, the synthetic control method recommends using the four ports of Genoa, Hamburg, La Spezia and Marsaxlokk too (however with different relative weights) to best replicate the total port traffic (all operators) in Piraeus before its privatization.[14]. This diagnosis over control groups will be kept in the next section when analyzing disaggregated ship level data. We will check the robustness of the results when limiting our sample to port calls in Piraeus and in these 4 ports.

Now that we discussed the choice of estimator and the choice of control group, let us show the evolution of coefficients when focusing first on the reduced group and then applying the De Chaisemartin and d'Haultfoeuille (2020) estimator to the restricted control group. Panels (a) and (b) in Figure 5 report the double-difference coefficients estimated by month for port calls in the port of Piraeus by the two groups of carriers. The difference between the two appears both on the magnitude and on the evolution towards the end of the period. COSCO-operated ships stop more frequently in the port of Piraeus than in ports of the control group: the number of port calls increases by 20 stops on average and stabilizes at this higher level throughout the period. Ships operated by carrier others than COSCO exhibit a higher increase (+50 stops) on average however this movement is soon paralleled by the general rise in the number of port calls in the ports of the control group.

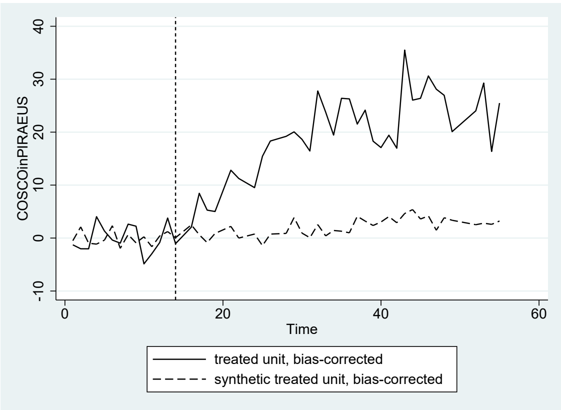
Applying our alternative estimator allows to clarify the picture: Figure 6 reports the coefficients obtained with the De Chaisemartin and d'Haultfoeuille (2020) estimator on the restricted sample

[14] To summarize, the synthetic control group when estimating coefficients for COSCO ships' port calls contains Genoa (68.3%), Hamburg (11.9%), and Kotka (19.8%). The synthetic control group when estimating the coefficients for non-COSCO ships' port calls contains Genoa (58%), Hamburg (11.8%), La Spezia (20%) and Marsaxlokk (10.3%). The synthetic control group when estimating the coefficients for the total number of port calls contains Genoa (58.8%), Hamburg (11.7%), La Spezia (19.7%) and Marsaxlokk (9.7%).

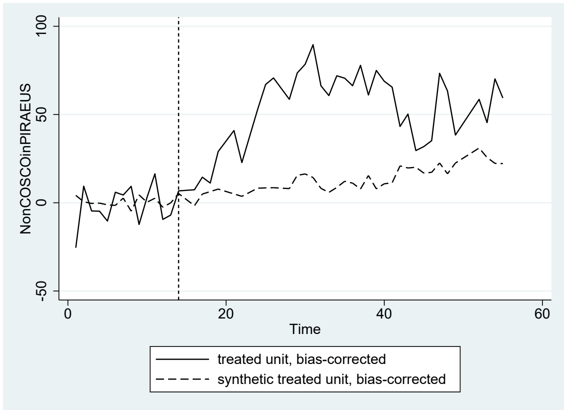
containing Piraeus and the four control ports (hence using the the synthetic control group used in Panel (b) of Figure 5.)

Interestingly, the placebo estimators now enclose 0 which is in support of the parallel trends assumption. Also the results on post-acquisition effects are very similar to those from the sample with the larger control group. Taken together, the results on the regressions at the aggregate port level suggest an increase in the port calls in Piraeus following its acquisition by COSCO, which seems to be largely driven by the increase in the number of COSCO vessels. Non-COSCO ships seem to benefit at first from the increased infrastructure, however once the new facilities are installed the additional number of stops in Piraeus does not persist. This feature questions the evolution of port choices in Piraeus and in other ports for container non operated by the COSCO company: did they become reluctant to use the port after the change in ownership, or did the conditions to use the port change once COSCO became the owner of the terminals ? Those are questions that we will investigate in Section 5. To end our investigation on the particularity of COSCO's vessels choices in Piraeus, we provide two figures comparing each port including Piraeus in the larger group of 32 core ports to the synthetic control group, in order to gauge the specificity of what is happening in the Greek port. Figure 7 displays the case of ships operated by COSCO and Figure 8 the one of non-COSCO vessels. In both figures the bold line depicts the double differences coefficient relative to the Piraeus. It appears that if there is a permanent increase in the size of the Piraeus as measured by the number and frequency of incoming vessels, the effect originates in a change of port choices made by COSCO-operated container ships. We investigate in Section 6 whether this outcome for the Chinese shipping line is paralleled by modifications in its port choices elsewhere in Europe.

Figure 5: Port-level Difference in Difference: Synthetic Control Method



(a) COSCO

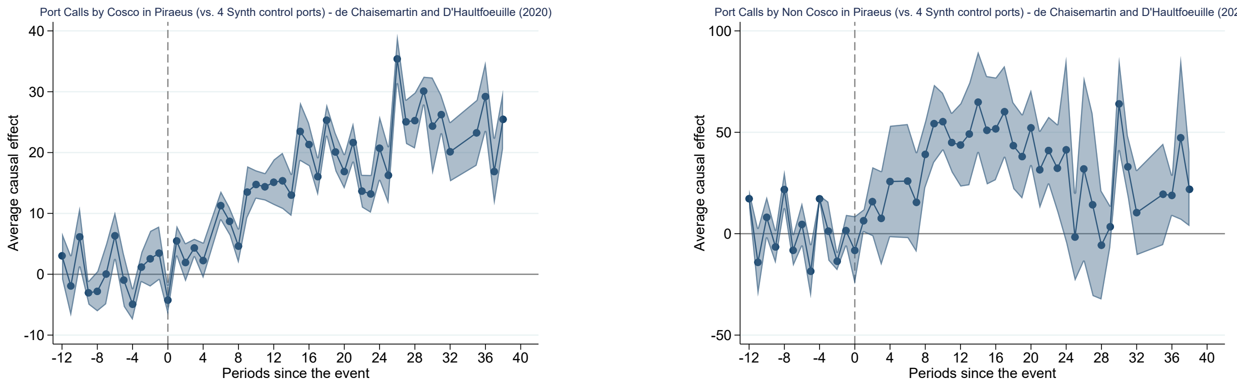


(b) Non-COSCO

Note: Figures generated by the allsynth command (Wiltshire, 2022). The matching variables are respectively the quarterly numbers of total ships and COSCO ships calling in each port before July 2016, the share of COSCO ships as well as information on the top decile of length and depth of the boats received in June 2016. The solid vertical line corresponds to July 2016 when Piraeus was purchased by COSCO. Panel (a) considers the number of port calls by COSCO ships. The control group is made of Genoa, Hamburg and Kotka with respective weights of 68.3, 11.9 and 19.8%. Panel (b) considers the number of port calls by non-COSCO operated ships. The control group is made of Genoa, Hamburg, La Spezia and Marsaxlokk with respective weights of 58, 11.8, 20 and 10.3%.

Figure 6: Port-level Difference in Difference (De Chaisemartin and d'Haultfoeuille (2020) estimator)

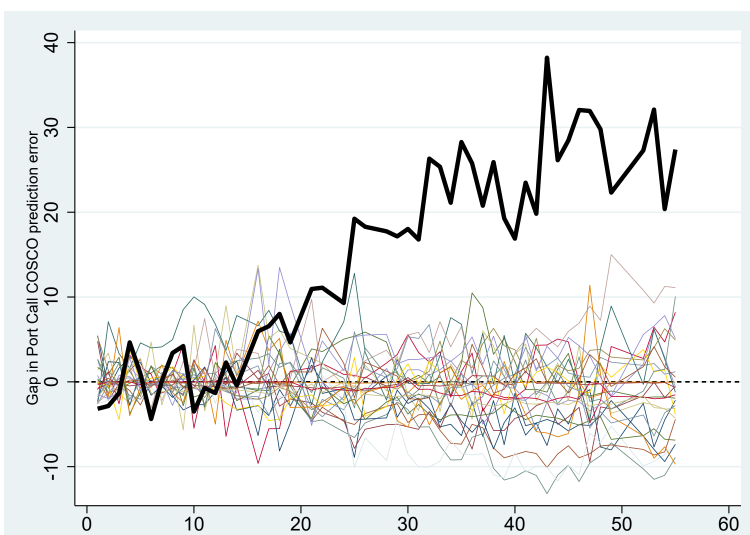
Piraeus vs. the 4 Core ports composing the Synthetic Control



(a) COSCO (b) Non-COSCO operators

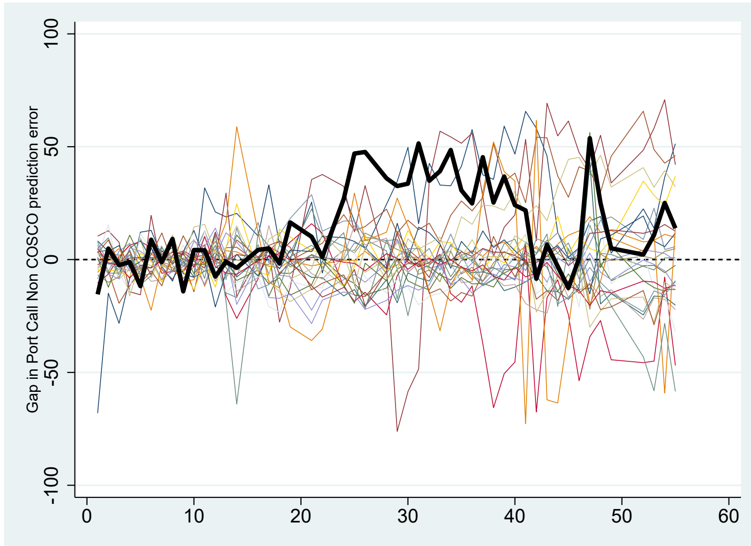
Note: Figures generated by the *did_multiplegt* command (De Chaisemartin and d'Haultfoeuille, 2020). Standard errors are calculated using 100 bootstrap replications, clustered on the port level, 95% confidence intervals are shown. Figures plots the dynamic treatment effects as well as the placebo tests of the parallel trends assumption. In both Panels (a) and (b) the sample of ports includes Piraeus and the four ports (Genoa, Hamburg, La Spezia and Marsaxlokk) used to build the Synthetic Control (Panel (b) of Figure 5). The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

Figure 7: Synthetic control group for all ports, COSCO ships



Note: Figure generated by the allsynth command (Wiltshire, 2022). The matching variables are respectively the quarterly numbers of total ships and COSCO ships calling in each port before July 2016, the share of COSCO ships as well as information on the top decile of length and depth of the boats received in June 2016. The bold black line corresponds to Piraeus. The other lines correspond to the gap between the number of port calls by COSCO ships in a given port and that its synthetic control unit.

Figure 8: Synthetic control group for all ports, non-COSCO ships



Note: Figure generated by the allsynth command (Wiltshire, 2022). The matching variables are respectively the quarterly numbers of total ships and COSCO ships calling in each port before July 2016, the share of COSCO ships as well as information on the top decile of length and depth of the boats received in June 2016. The bold black line corresponds to Piraeus. The other lines correspond to the gap between the number of port calls by non-COSCO ships in a given port and that its synthetic control unit.

5 Ship-level port choices

We now exploit the ship-level granularity of the AIS and study the decision made by a ship to stop in a given port on a given date. The results at the aggregate level found in the previous Section suggest that the monthly number of vessels received by the port of Piraeus has increased following its takeover by COSCO compared to before, in particular through an increase in the number of vessels operated by COSCO. Three mechanisms may explain this rise: a change in the intensive margin (higher frequency of stops per ship), a change in the extensive margin (ships that did not stop in Piraeus now stop there) for ships that used to serve Europe, as well as the arrival of new ships that did not serve Europe before July 2016. Moving to the ship level analysis, we focus on the first two margins and examine whether carriers modified either their frequency of stops in Piraeus or the number of ships that choose to stop in Piraeus. We investigate whether the relative probability of a given ship stopping in Piraeus (compared to other comparable ports) has increased after the port's acquisition by COSCO especially for ships operated by COSCO. The analysis thus exploits the variation within ship over time and across ports. As detailed at end of the previous Section, we are also interested in learning whether other carriers turned away from the port once controlled in majority by COSCO.

5.1 The COSCO-bias

Our empirical approach is based on an explained variable which is a dummy indicating whether ship p calls in port p at date t. Hence, when a ship s calls in a port p it is coded as a 1 while the other ports not chosen for this call are therefore coded as zeros for this date. We estimate the following Equation 2 with a linear probability model:

$$0/1 \text{ Port Call}_{spym} = \beta_0 \text{ Piraeus}_p + \beta_1 \text{ Piraeus}_p \times \text{Post}_{ym} + \beta_2 \text{ COSCO}_s \times \text{Piraeus}_p \times \text{Post}_{ym} + \mu_{sym} + \nu_{sp} + \epsilon_{spt} \quad (2)$$

The comparison of traffic before/after the privatization of Piraeus is picked up by the interaction between the dummy denoting Piraeus and the Post_{ym} dummy, which equals 1 in each year-month from July 2016 onwards. All specifications include standard errors clustered at both the ship and port levels, to account for the correlation between port calls within container ships and ports respectively. The data spans July 2015 to December 2019. As detailed in Section 3.1, we clean the data to remove duplicates (multiple occurrences of a ship in a port on the same day) and to remove ships that change operators over the period.[15] The ship level dataset covers a total of 144,835 calls of which 109,027 in the 32 Core ports + Piraeus (of which 5,420 in Piraeus) by 1,930 distinct ships of which 135 COSCO ships (the COSCO ships make 765 port calls in Piraeus).

Table 3 shows the first ship-level results in which the port calls in the port of Piraeus are compared to different control goups. Columns 1 and 2 correspond to the 32 core European ports with more than 50 monthly port calls over the period listed in Table 2, hence the size of the sample (3,597,891=109,027×33). Columns 3 to 6 focus on the restricted sample where port calls in Piraeus are compared with those in the four ports with similar ship visit numbers before July 2016 as identified when applying the synthetic control method on the total number of ports calls (see Panel (b) of Figure 5). The sample is much lower and includes 117,830 observations corresponding to 23,566 port calls in Piraeus (5,420), Genoa (4,343), Hamburg (9,210), La Spezia (2,442), and Marsaxlokk (2,151).

The odd-numbered columns include both the dummy for Piraeus and the interaction between Piraeus and Post_{ym} dummy. The even-numbered columns add ship-port fixed effects which absorb the intrinsic time-invariant specificity of ports. It is worth noting that while the Piraeus dummy is positive and significant when the comprehensive sample is used, the dummy is not distinguishable from zero when the sample is limited to the most-similar ports. This result is reassuring that the control group is more suitable to ensure a valid comparison for Piraeus and identify the repercussions from its privatization. The interaction between Piraeus and Post_{ym} measures, for container ships calling in Europe, the difference before/after Piraeus' privatization in port calls in Piraeus compared to the before/after difference in port calls in other ports. The interaction term attracts a positive and significant coefficient in the comprehensive sample as well as in the restrictive one. This hence confirms the results found using the aggregate data in Section 4 of a relative rise in the propensity of a given ship to stop in Piraeus after it got acquired by COSCO. In magnitude, columns 4 and 6 show that the probability of calling in Piraeus (relative to the other ports) is on average 5 percentage

[15] We must point out that in some months (in particular August 2016, April 2018 and August 2018) the antenna we exploit had operational problems, which has prevented the reception of information for several days. These problems affect the data for all ports equally and are taken into account through time fixed effects.

points higher after Piraeus' privatization (July 2016-December 2019) than before (June 2015-June 2016): 5.7% for column 4 and 4.5% in column 6.

Table 3: Difference in Difference in Piraeus for COSCO: alternative control groups

Explained Variable	Dummy 0/1 Port Call by Ship$_s$ in Port$_p$ at date t					
	1	2	3	4	5	6
Piraeus	0.010^c		-0.021		-0.003	
	(0.006)		(0.075)		(0.042)	
Piraeus × Post	0.013^a	0.018^a	0.076^b	0.057^b	0.064^b	0.045^b
	(0.001)	(0.001)	(0.018)	(0.014)	(0.020)	(0.016)
Observations	3,597,891		117,830		117,830	
Fixed Effects						
Ship Year Month	Yes	Yes	Yes	Yes	Yes	Yes
Port	No	-	No	-	No	-
Ship-Port	No	Yes	No	Yes	No	Yes
Control ports	32 Core ports		Synth Control Group: 4 ports			
Synth Control weights	No		No		Yes	

Note: Heteroskedasticity-robust standard errors two-way clustered at the ship level and at the port level appear in parentheses. ^{a}, ^{b} and ^{c} indicate significance at the 1%, 5% and 10% confidence levels. Columns 1 to 2 consider port calls in Piraeus and the Core 32 ports with more than 50 monthly port calls over the period listed in Table 2. Columns 3 to 6 consider port calls in Piraeus and the 4 ports identified by the synthetic control methodology to reproduce Piraeus pre-acquisition number of port calls (see Panel (b) of Figure 5). The control group is made of Genoa, Hamburg, La Spezia and Marsaxlokk. Columns 5 and 6 use their respective "synthetic control" weights of 58.8, 11.7, 19.7 and 9.7%.

Table 4 builds on the columns 2 and 4 of Table 3 and investigates whether this rise mostly relates to COSCO ships as suggested in the aggregate results from Section 4. We add an additional element which helps understanding the specificity of COSCO vessels' behavior. Compared to column 1, column 2 adds an interaction between Piraeus and Post$_{ym}$ for ships that visited China over the period (2015-2019). The objective is to check whether the higher propensity of COSCO ships to call in Piraeus solely reflect the fact that they may serve the Chinese market. Column 3 decomposes the Post$_{ym}$ term into yearly terms for a more-detailed understanding of the timing of the effect. We use two distinct period dummy in 2016 to separate the period before the privatization from that after July 2016, the month when COSCO acquired Piraeus acts as the benchmark. Columns 4 to 6 follow the same logic on the restricted sample of comparable ports.

Regardless of the sample of ports considered, there is an increase in the propensity of COSCO ships to use Piraeus after its privatization. Our raw data suggest that the average probability of a COSCO ship stopping in Piraeus while in Europe increases from 15% to 45% over the period. Columns 3 and 6 show that this increase is not reflected in the ships serving China at any point in the period, suggesting that it is the fact of being operated by COSCO and not the serving of the Chinese market that distinguishes the ships serving Piraeus more systematically.

It is important to note that, logically linked to the modality of selection of the ports in the restricted control group, there is no pre-existing difference between the port of Piraeus and the

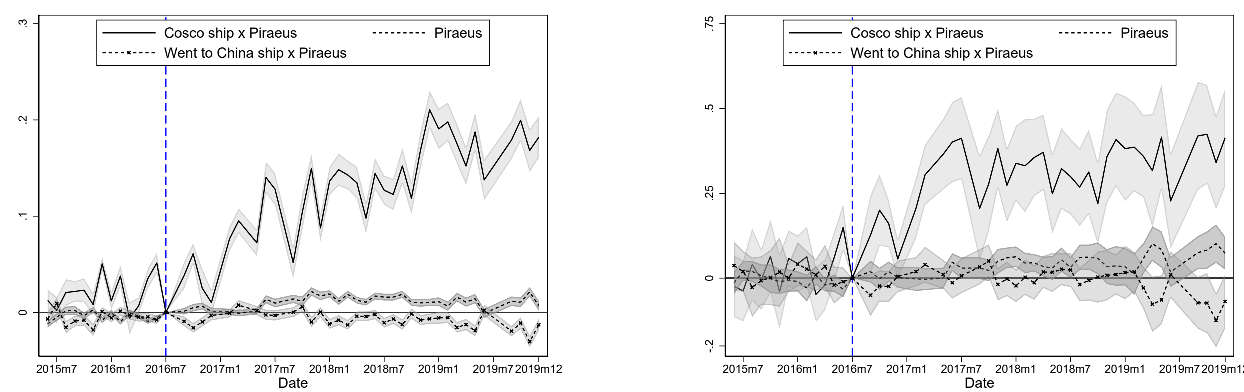
Table 4: Double and Triple differences for Piraeus: COSCO, non-COSCO and trips to China

Explained Variable	Dummy Port Call by $Ship_s$ in $Port_p$ at date t					
	1	2	3	4	5	6
Control ports	32 Core ports			Synth Control Group: 4 ports		
Piraeus×Post	0.014^a	0.015^a		0.040^b	0.047^b	
	(0.001)	(0.001)		(0.013)	(0.011)	
Piraeus×2015			-0.003^c			0.004
			(0.002)			(0.017)
Piraeus ×Jan-June 2016			-0.005^a			-0.016
			(0.001)			(0.014)
Piraeus×Aug-Dec 2016			0.004^c			0.013
			(0.002)			(0.015)
Piraeus×2017			0.010^a			0.028
			(0.002)			(0.016)
Piraeus×2018			0.015^a			0.047^c
			(0.002)			(0.018)
Piraeus ×2019			0.012^a			0.068^c
			(0.003)			(0.029)
COSCO×Piraeus×Post	0.100^a	0.101^a		0.255^a	0.261^a	
	(0.006)	(0.006)		(0.038)	(0.037)	
COSCO×Piraeus×2015			0.020^a			0.006
			(0.005)			(0.041)
COSCO×Piraeus×Jan-June 2016			0.022^a			0.035
			(0.004)			(0.040)
COSCO×Piraeus×Aug-Dec. 2016			0.032^a			0.130^b
			(0.007)			(0.043)
COSCO×Piraeus×2017			0.101^a			0.307^a
			(0.006)			(0.055)
COSCO×Piraeus×2018			0.141^a			0.314^a
			(0.007)			(0.060)
COSCO×Piraeus×2019			0.179^a			0.371^a
			(0.010)			(0.077)
Ship visited China×Piraeus×Post		-0.004			-0.020	
		(0.002)			(0.032)	
Ship visited China×Piraeus×2015			-0.006^c			0.005
			(0.003)			(0.037)
Ship visited China×Piraeus×Jan-June 2016			-0.004^c			0.015
			(0.002)			(0.028)
Ship visited China×Piraeus×Aug-Dec. 2016			-0.009^a			-0.020
			(0.002)			(0.024)
Ship visited China×Piraeus×2017			-0.000			0.014
			(0.003)			(0.024)
Ship visited China×Piraeus×2018			-0.008^a			0.004
			(0.003)			(0.027)
Ship visited China×Piraeus×2019			-0.014^a			-0.049
			(0.003)			(0.040)
Observations	3,597,891			117,830		
Fixed Effects						
Ship Year Month	Yes	Yes	Yes	Yes	Yes	Yes
Ship-Port	Yes	Yes	Yes	Yes	Yes	Yes

Note: Heteroskedasticity-robust standard errors two-way clustered at the ship level and at the port level appear in parentheses. [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence levels. Columns 1 to 3 consider port calls in Piraeus and the Core 32 ports with more than 50 monthly port calls over the period listed in Table 2. Columns 4 to 6 consider port calls in Piraeus and the 4 ports identified by the synthetic control methodology to reproduce Piraeus pre-acquisition number of port calls (see Panel (b) of Figure 5). The control group is made of Genoa, Hamburg, La Spezia and Marsaxlokk.

4 ports selected before the moment of privatization of the former. Column 6 reveals that the timing of the increase corresponds to the timing of privatization and refutes the idea that there is already a prior divergence: none of the interactions between COSCO×Piraeus and period dummies before July 2016 are significant. Columns 3 and 6 of Table 4 plot the estimated double coefficients Piraeus×Post$_{ym}$, triple coefficients for COSCO×Piraeus×Post$_{ym}$, and the ones for Ship visited China×Piraeus×Post$_{ym}$ over the whole period. The results displayed in Figure 9 show the higher frequency of COSCO ships calling in Piraeus disentangled from the fact that the ship calling in Piraeus is traveling on routes which serve the Chinese market. They confirm that the specific increase in the port of Piraeus observed after the privatization of the port is specific to COSCO vessels and is not explained by the fact that these vessels are more engaged in trade with China.

Figure 9: Piraeus Difference in Difference specific to COSCO ships



(a) Piraeus vs. the 32 Core ports

(b) Piraeus vs. the 4 Core ports composing the Synthetic Control

This figure plots the ranges of coefficients on the monthly interactions for Piraeus, Piraeus×COSCO and Ship visited China×Piraeus. Panel (a) uses a specification similar to that of column 3 in Table 4, where Piraeus is compared to the 32 European "core" ports (other than Piraeus) which receive more than 50 monthly port calls over the period as listed in Table 2. Panel (b) uses a specification similar to that of column 6 in Table 4, where Piraeus is compared to the 4 ports identified by the synthetic control methodology to reproduce Piraeus pre-acquisition number of port calls (see Panel (b) of Figure 5). The control group is made of Genoa, Hamburg, La Spezia and Marsaxlokk. The coefficients are estimated with respect to their respective values in July 2016 (which is absorbed in the ship-port fixed effect). The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

5.2 A bias towards large container ships

We now investigate whether our results are specific to ships of a particular capacity or whether they apply to all ships. The twenty-foot equivalent units (TEU) unit may serve to separate boats into categories depending on their capacity: Container ships are distinguished into feeders (below 3,000 TEUs), Panamax and Post Panamax (capacity between 3,000 and 10,000 TEUs) and New Panamax (or Neopanamax) starting at 10,000 TEUs.[16]

Table 5 reports the results of the triple difference term for COSCO in Piraeus. Two panels allow to show either both the double and triple difference results (upper panel) or only the triple difference coefficients (lower panel), since the lower panel controls for time-varying features of ports through port-year-month fixed effects. The columns differ in that they sequentially rely on

[16]The largest category, the Ultra Large Container Vessel (ULCV) have a capacity of 14,501 TEUs and higher.

the comprehensive and the limited sample of control ports (Columns 1 to 4 and Columns 5 to 8 respectively).

Table 5: Triple Difference in Piraeus for COSCO: ship capacity checks

Explained Variable	Dummy Port Call by $Ship_s$ in $Port_p$ at date t							
	1	2	3	4	5	6	7	8
Control ports	32 Core ports				Synth Control Group: 4 ports			
Ship Capacity (TEU)	All	< 3,000	3,000-10,000	≥ 10,000	All	< 3,000	3,000-10,000	≥ 10,000
Piraeus × Post	0.014[a]	0.015[a]	0.025[a]	-0.009[a]	0.040[b]	0.012	0.142[a]	-0.046
	(0.001)	(0.002)	(0.001)	(0.003)	(0.013)	(0.015)	(0.021)	(0.031)
COSCO × Piraeus × Post	0.100[a]	0.011	0.120[a]	0.171[a]	0.255[a]	0.052	0.300[a]	0.394[a]
	(0.006)	(0.009)	(0.008)	(0.007)	(0.038)	(0.050)	(0.041)	(0.056)
Fixed Effects								
Ship-Year-Month	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ship-Port	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port-Year-Month	No	No	No	No	No	No	No	No
Explained Variable	Dummy Port Call by $Ship_s$ in $Port_p$ at date t							
	1	2	3	4	5	6	7	8
Control ports	32 Core ports				Synth Control Group: 4 ports			
Ship Capacity in TEUs	All	< 30,00	3,000-10,000	≥ 10000	All	< 3,000	3,000-10,000	≥ 10,000
COSCO × Piraeus × Post	0.100[a]	0.011	0.121[a]	0.170[a]	0.258[a]	0.051	0.286[a]	0.397[a]
	(0.006)	(0.009)	(0.007)	(0.007)	(0.038)	(0.049)	(0.037)	(0.055)
Fixed Effects								
Ship-Year-Month	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ship-Port	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Port-Year-Month	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,595,680	1,624,854	1,335,444	635,382	117,105	52,640	39,155	25,310

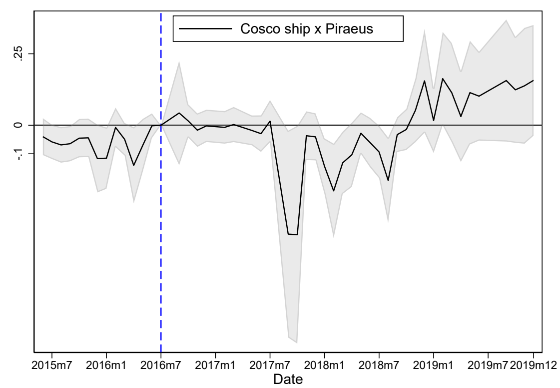
Note: Heteroskedasticity-robust standard errors two-way clustered at the ship level and at the port level appear in parentheses. [a], [b] and [c] indicate significance at the 1%, 5% and 10% confidence levels. Columns 1 to 4 consider port calls in Piraeus and the Core 32 ports with more than 50 monthly port calls over the period listed in Table 2. Columns 5 to 8 consider port calls in Piraeus and the 4 ports identified by the synthetic control methodology to reproduce Piraeus pre-acquisition number of port calls (see Panel (b) of Figure 5). The control group is made of Genoa, Hamburg, La Spezia and Marsaxlokk. The sample in columns 3 and 7 includes ships with capacity between 3,000 and 10,000 TEUs. The sample in columns 4 and 8 includes ships with capacity above 10,000 TEUs.

Importantly, the different columns investigate the conditioning role of ship capacity by splitting the sample into three sub-groups. Columns 2 and 6 focus on feeders, i.e. vessels with a capacity of less than 3,000 TEUs. Columns 3 and 7 consider Panamax and Post Panamax with capacities between 3,000 and 10,000 TEUs while Columns 4 and 8 zoom on the largest container ships. The results are consistent between the larger sample and the smaller sample of ports to which Piraeus is compared. They suggest that the increase in COSCO's vessel stoppages in Piraeus after its privatization does not concern feeders, i.e., the small vessels that collect shipping containers from ports where larger vessels do not go to transport them to central container terminals, such as Piraeus, where they are loaded on larger vessels. It seems that following its acquisition by COSCO, the port of Piraeus has become a more systematic port of call for the Chinese operator's large container ships. This increase in traffic for large COSCO-branded container ships is specific to this operator and is not found among its competitors. The increased stopping propensity is higher for sea-going vessels with capacities above 10,000 TEUs. Estimates are even larger in columns 5 to 6, where the 4 most-similar ports of Genoa, Hamburg, La Spezia and Marsaxlokk are the control group. By contrast, while there is an increase in stops by feeders in Piraeus, this is not particularly marked for COSCO vessels.

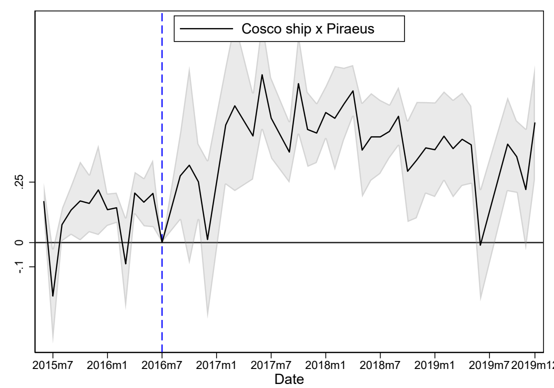
Figure 10 plots the monthly interactions between COSCO×Piraeus and time for the three ship size subsamples studied in columns 6, 7 and 8 of Table 5. We can observe how feeders (Panel a) behave differently from larger ships, Panamax and Post-Panamax vessels with capacities between 3,000 and 10,000 TEUs (Panel b) and from New Panamax vessels above 10,000 TEUs (Panel c).

Figure 10: Triple Difference for COSCO ships in Piraeus : different ship capacity

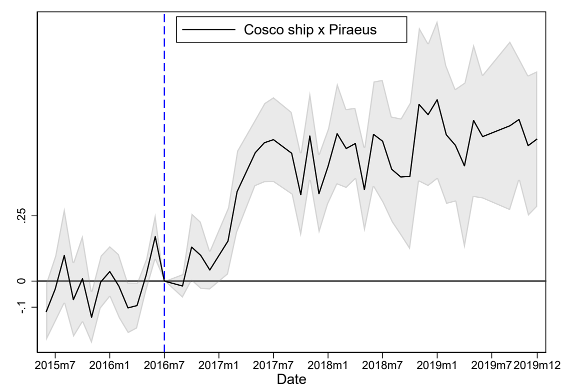
Piraeus vs. the 4 Core ports composing the Synthetic Control



(a) Ships with capacity $<$ 3,000 TEUs



(b) Ships with capacity 3,000-10,000 TEUs



(c) Ships with capacity $\geq$ 10,000 TEUs

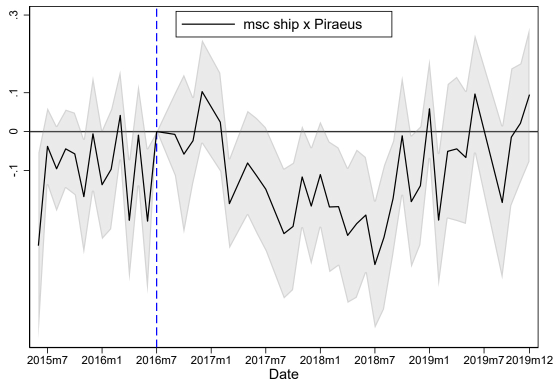
This figure plots the ranges of coefficients on the monthly interactions for Piraeus×COSCO in a specification similar to that of columns 6 to 8 specification of Table 5, where Piraeus is compared to Genoa, Hamburg, La Spezia and Marsaxlokk (the four ports making up the synthetic control unit). The sample includes respectively ships with a capacity below 3,000 TEUs in Panel (a), with a capacity between 3,000 and 10,000 TEUs in Panel (b) and with a capacity above 10,000 TEUs in Panel (c). The coefficients are estimated with respect to their respective values in July 2016 (which is absorbed in the ship-port fixed effect). The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

5.3 No crowding out between operators

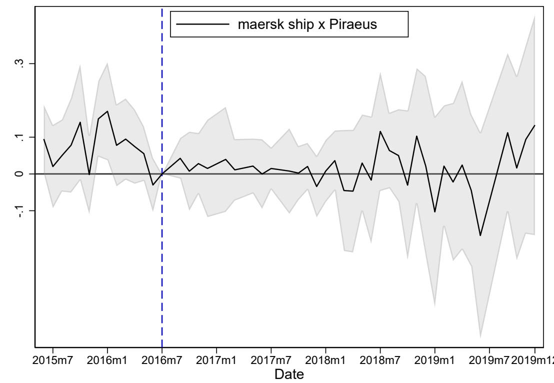
Due to capacity constraints, the increase in the number of calls by COSCO vessels in Piraeus could be at the expense of other operators. We investigate this possible crowding out effect by looking at the pattern of use of Piraeus by operators other than COSCO. Figures 11, 12 and 13 duplicate our triple-difference results from Figure 10 for the six main operators listed in Table 1.

Figure 11: Triple Difference : Piraeus × Specific operator (ship capacity $<$ 3,000 TEUs)

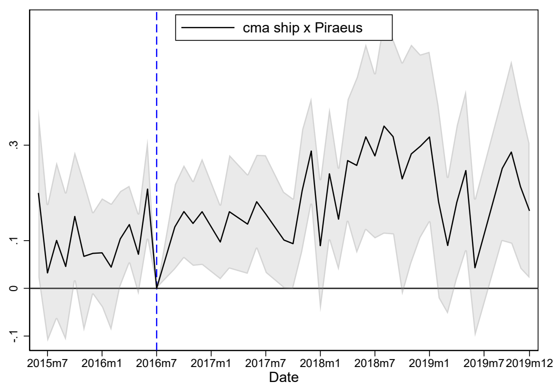
Piraeus vs. the 4 Core ports composing the Synthetic Control



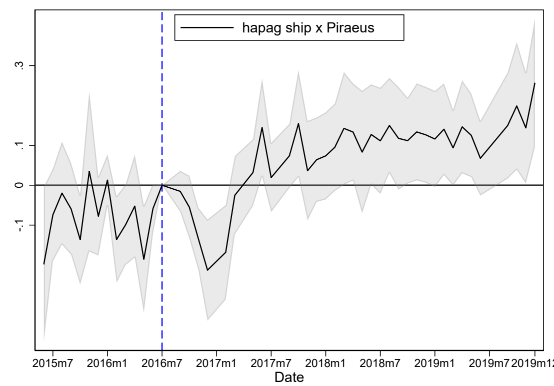
(a) MSC



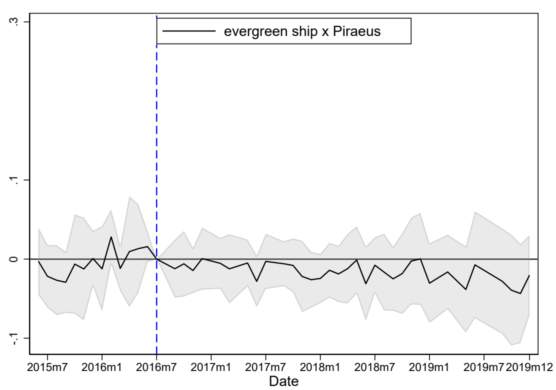
(b) Maersk



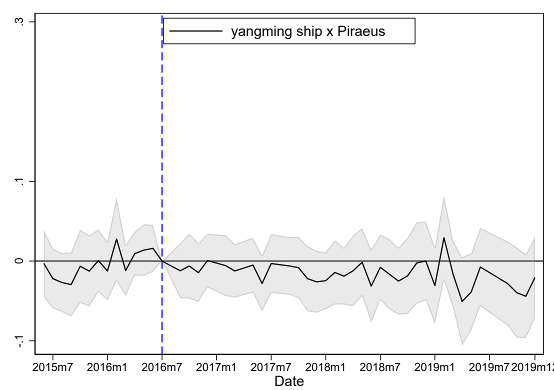
(c) CMA-CGM



(d) Hapag



(e) Evergreen

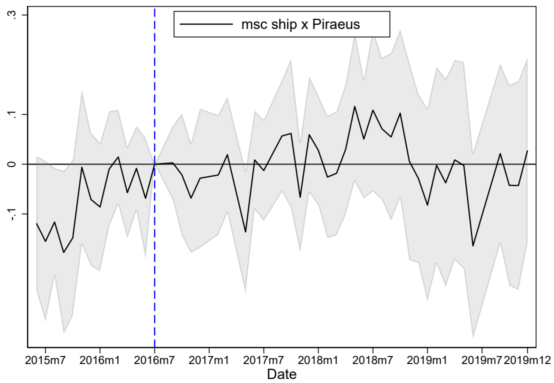


(f) Yang Ming

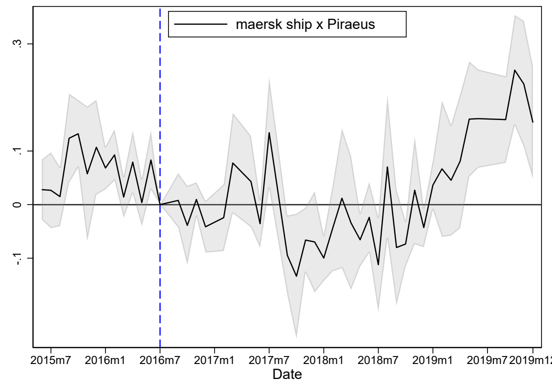
This figure plots the ranges of coefficients on the monthly interactions between a ship operator and Piraeus in a specification similar to the column 6 of Table 5 applied to a sample from which COSCO ships are removed. Only ships with capacity below 3,000 TEUs are considered. In this specification, Piraeus is compared to Genoa, Hamburg, La Spezia and Marsaxlokk, the four ports identified in the synthetic control group method applied to aggregate data. The coefficients are estimated with respect to their respective values in July 2016 (which is absorbed in the ship-port fixed effect). The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

Figure 12: Triple Difference : Piraeus×Specific operator (ship capacity 3,000-10,000 TEUs

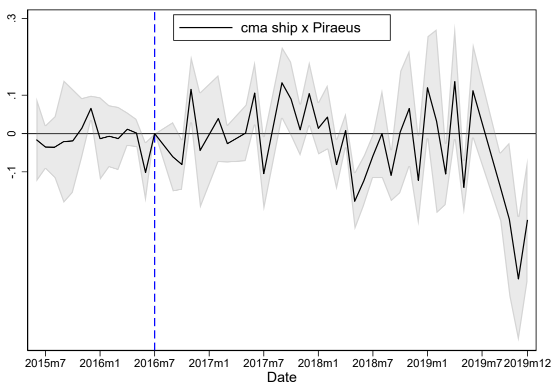
Piraeus vs. the 4 Core ports composing the Synthetic Control



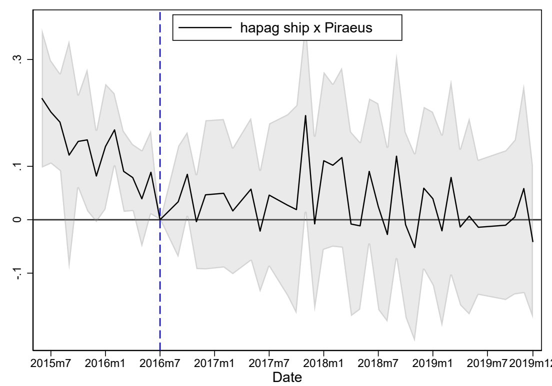
(a) MSC



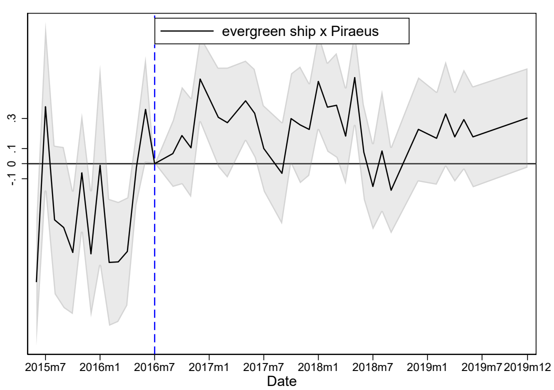
(b) Maersk



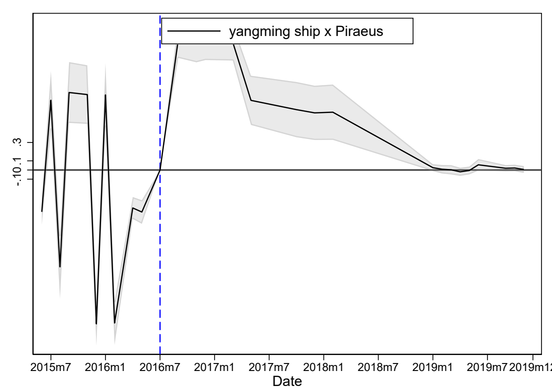
(c) CMA-CGM



(d) Hapag



(e) Evergreen

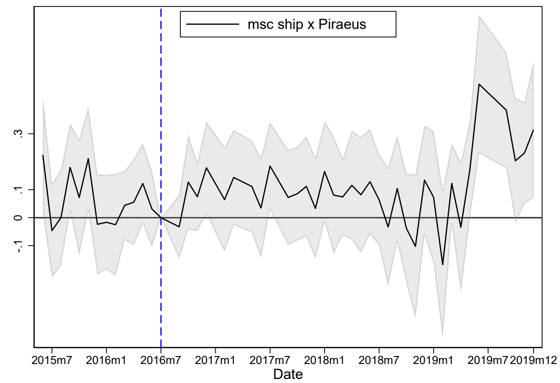


(f) Yang Ming

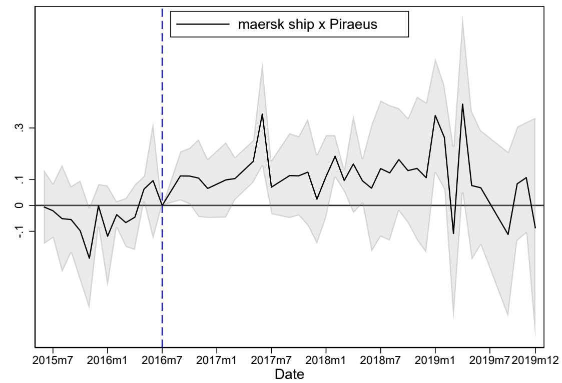
This figure plots the ranges of coefficients on the monthly interactions between a ship operator and Piraeus in a specification similar to the column 7 of Table 5 applied to a sample from which COSCO ships are removed. Only ships with capacity between 3,000 and 10,000 TEUs are considered. In this specification, Piraeus is compared to Genoa, Hamburg, La Spezia and Marsaxlokk, the four ports identified in the synthetic control group method applied to aggregate data. The coefficients are estimated with respect to their respective values in July 2016 (which is absorbed in the ship-port fixed effect). The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

Figure 13: Triple Difference : Piraeus×Specific operator (capacity $\geq$ 10,000 TEUs)

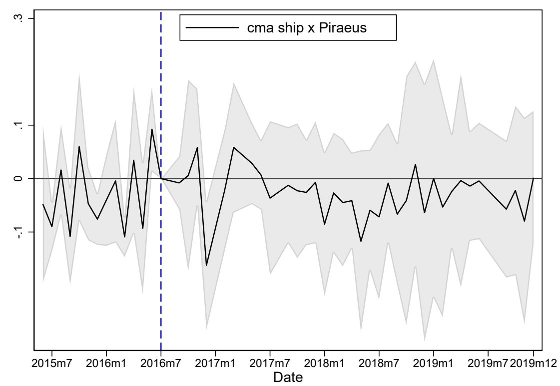
Piraeus vs. the 4 Core ports composing the Synthetic Control



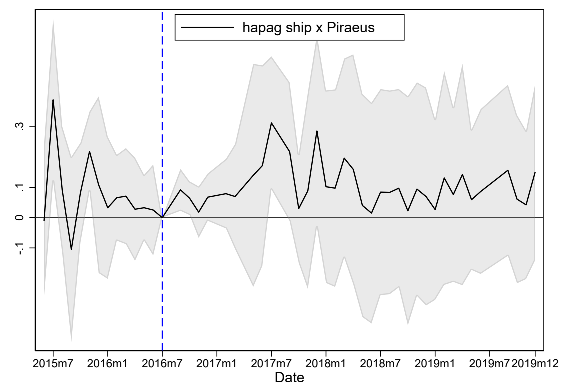
(a) MSC



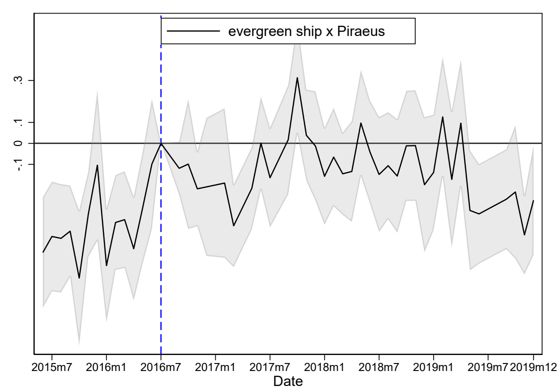
(b) Maersk



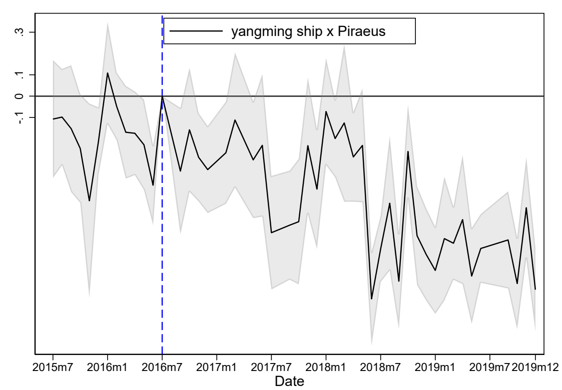
(c) CMA-CGM



(d) Hapag



(e) Evergreen



(f) Yang Ming

This figure plots the ranges of coefficients on the monthly interactions between a ship operator and Piraeus in a specification similar to the column 8 of Table 5 applied to a sample from which COSCO ships are removed. Only ships with capacity above 10,000 TEUs are considered. In this specification, Piraeus is compared to Genoa, Hamburg, La Spezia and Marsaxlokk, the four ports identified in the synthetic control group method applied to aggregate data. The coefficients are estimated with respect to their respective values in July 2016 (which is absorbed in the ship-port fixed effect). The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

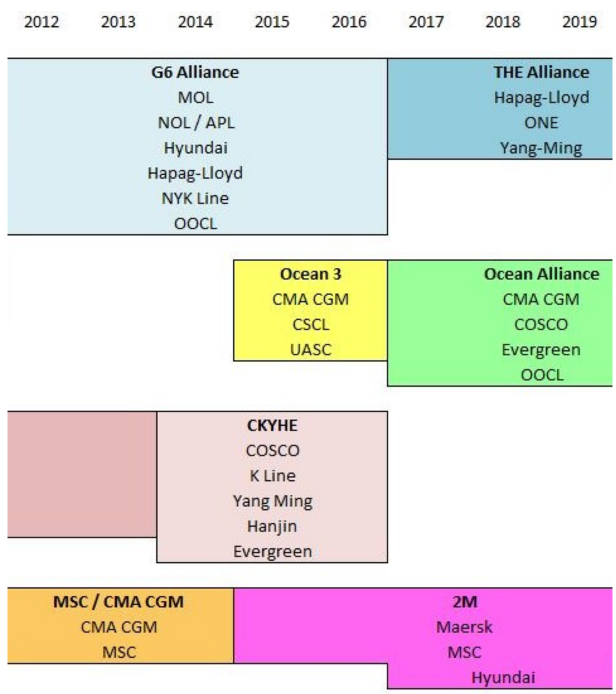
These include MSC, Maersk, CMA-CGM, Hapag-Lloyd, Yang Ming and Evergreen.[17] The six

[17] We do not look at Ocean since it made its debut in 2016 as a joint venture between NYK (Nippon Yusen Kaisha),

distinct estimates are based on the sample used in the left panel of Table 5 in which the observations for COSCO ships have been removed. The triple-interaction term between Piraeus, time dummies, and a dummy for each of these operators is estimated comparing port calls in Piraeus to those in the four ports (Genoa, Hamburg, La Spezia and Marsaxlokk), identified in the synthetic control group method applied to aggregate data.

Figures 11, 12 and 13 show that the increase in the use of Piraeus by COSCO vessels after its acquisition was not at the expense of the vessels of other operators: the sharp rise in the probability of COSCO ships to stop in Piraeus is not mirrored in that of non-COSCO ships. There is one notable exception with Yang Ming for larger ships (panel f of Figure 13).[18] The Taiwanese company was part a an alliance with COSCO until April 2016 (this alliance also included Evergreen and K Line). In April 2016, as described in Figure 14 the four existing alliances were reshuffled into 3: (1) the already existing 2M alliance (between Maersk and MSC) remained but expanded to include Hyundai, (2) Ocean Alliance was created uniting COSCO, Evergreen and CMA-CGM, (3) THE alliance was created between Yang-Ming and K Line (which hence separated from their former alliance with COSCO and Evergreen) and Hapag-Lloyd and a few other former members of the alliance around Hapag-Lloyd.

Figure 14: Operator alliances



Source: Wikipedia.

MOL (Mitsui O.S.K. Lines) and K Line (Kawasaki Kisen Kaisha). It was officially created in July 2017.

[18]Results available upon request show that this finding is robust when the comprehensive sample of 32 Core ports is used for the control group.

6 Investigating Port Substitution

Our third question is whether the higher propensity of COSCO ships to call in Piraeus happens in addition to or as a substitute to port calls in other ports. This interrogation interacts with the open issue of the purpose of the port of Piraeus. Indeed if China continues to use Piraeus as a main hub to organize its trade with Europe, then we will observe that Piraeus will probably allow the largest vessels not to travel up to some other ports of Europe and choose Piraeus instead. In the case China decides to make of Piraeus not only a transshipment port but progressively a gateway port serving a large hinterland, then substitution effect with northern ports can be expected to be even larger.

To study this phenomenon we estimate whether the large geographical areas in which European ports are located evolve differently from the evolution observed in Piraeus. Our approach here is to compare the different ports in the control group with each other to show whether some of them have experienced a reduction in COSCO ship traffic that coincides with the privatization of Piraeus and its more systematic use as a hub by COSCO ships.

From the econometric point of view the substitution scenario obviously calls into question the implicit assumption that underlies the difference-in-differences estimator, namely the assumption of no impact for the control group. For this we use the extended sample including the 32 European "core" ports (other than Piraeus) which receive more than 50 monthly port calls over the period as listed in Table 2.

We first take into consideration the geographical location of ports and investigate a regional substitution effect whereby the rise of Piraeus would divert ships from ports in a specific sub-region. Since Piraeus is located in the Mediterranean it might seem possible that the COSCO ships that increasingly stop in Piraeus after its privatization will no longer stop in other Mediterranean ports where they used to stop. To investigate such a pattern, we use the 4 zones referred to in Table 2, i.e Baltic, NorthSea, Atlantic and Mediterranean Sea.[19] Using the Baltic ports as the reference (as they are the furthest from Piraeus and probably the least substitutable for Piraeus), we estimate the triple interaction term between COSCO$\times$ Post and a dummy for Piraeus, the other Mediterranean sea ports, the North Sea ports and the Atlantic ports. Results are reported in Table 6 where the whole sample of ships is considered in Column 1 before it is split according to ship capacity: column 2 zooms on ships with a capacity less than 3,000 TEUs, column 3 covers capacities between 3,000 and 10,000 TEUs while column 4 focuses on ships with capacity above 10,000 TEUs.

When looking at all ships together no clear substitution effect emerges. The results in column 2 confirm that the bulk of the action occurs on vessels larger than 3,000 TEUs. For the largest vessels (over 10,000 TEUs) that are engaged in intercontinental connections, the increase in COSCO vessel traffic in Piraeus seems to be partly at the expense of the North Sea and Atlantic ports (Column 4). For medium-sized ships, there does seem to be a partial replacement between a stop in Piraeus and a stop in another Mediterranean port. On the other hand, the positive and significant coefficient

[19]The comprehensive sample includes 13 Mediterranean Core Ports other than Piraeus: Algeciras, Barcelona, Genoa, Gioia Tauro, La Spezia, Livorno, Marseille, Valencia, Ambarli, Koper, Marsaxlokk, Mersin and Venice.

Table 6: Triple Difference in Piraeus for COSCO: ship capacity checks

Explained Variable	Dummy Port Call by $Ship_s$ in $Port_p$ at date t			
	1	2	3	4
Control ports	32 Core ports			
Ship Capacity in TEUs	All	< 3000	3000-10000	≥ 10000
COSCO × Piraeus × Post	0.104^a	0.011	0.140^a	0.151^a
	(0.011)	(0.020)	(0.011)	(0.011)
COSCO × MedCore13 Ports × Post	-0.009	-0.013	-0.017^b	-0.001
	(0.009)	(0.016)	(0.007)	(0.007)
COSCO × NorthSea6 Ports × Post	-0.021	-0.029	0.016^b	-0.035^c
	(0.015)	(0.036)	(0.007)	(0.019)
COSCO × Atlantic7 Ports × Post	-0.014	-0.018	-0.002	-0.018^c
	(0.010)	(0.020)	(0.005)	(0.010)
Observations	3,595,680	1,624,854	1,335,444	635,382
Fixed Effects				
Ship-Year-Month	Yes	Yes	Yes	Yes
Ship-Port	Yes	Yes	Yes	Yes
Port-Year-Month	Yes	Yes	Yes	Yes

Note: Heteroskedasticity-robust standard errors two-way clustered at the ship level and at the port level appear in parentheses. ^{a}, ^{b} and ^{c} indicate significance at the 1%, 5% and 10% confidence levels. Columns 1 to 4 consider port calls in Piraeus and the Core 32 ports with more than 50 monthly port calls over the period listed in Table 2. The sample in column 2 includes ships with a capacity less than 3,000 TEUs. In column 3 it covers capacities between 3,000 and 10,000 TEUs while in column 4 only ships with capacity above 10,000 TEUs are considered.

on the interaction term between COSCO×Post and the North Sea ports[20] suggests that the latter are benefiting from increased call frequency of COSCO vessels following the acquisition of the port of Piraeus by the Chinese operator. One possible explanation is that some of the huge COSCO container ships, presumably from Asia, which now stop in Piraeus, stop serving a North Sea port on their own. On the other hand, some of the cargo is put on smaller COSCO ships which increase the number of their rotation to these ports. Thus the privatization of Piraeus has imposed the Greek port as a hub for COSCO's European market: containers brought in by New Panamax ships above 10,000 TEUs no longer systematically arrive directly in the major ports of Western Europe, they are partly dispatched during the call at Piraeus on board smaller COSCO ships that will make the connection between Piraeus and these major European ports.

Figure 15 reports the monthly triple difference estimates obtained from the regressions of Table 6. The lack of significance or the low value of the coefficients for the Mediterranean ports suggests that the COSCO vessel stops in Piraeus did not simply replace pre-existing COSCO vessel stops in other Mediterranean ports but largely added up. This may seem surprising given that a number of Mediterranean ports have precisely the same positioning as Piraeus, namely be dedicated to transhipment activities which is highly contestable since they are unrelated to the attractivity of the ports' hinterland (Ducruet and Notteboom, 2012).[21] In our sample of the 32 Core ports, 5 ports are identified as transhipment hubs by Notteboom et al. (2019): they include three Mediterranean ports (Algeciras, Gioia Tauro and Marsaxlokk) as well as Sines (Portugal) and Gdansk (Poland).[22]

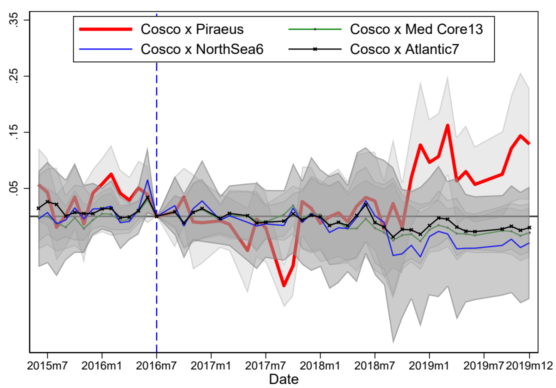
[20] The 6 North Sea Ports are Antwerp, Bremerhaven, Hamburg, Moerdijk, Rotterdam and Wilhelmshaven.

[21] According to Notteboom et al. (2019), up to 85% of Piraeus' activities are dedicated to transhipment.

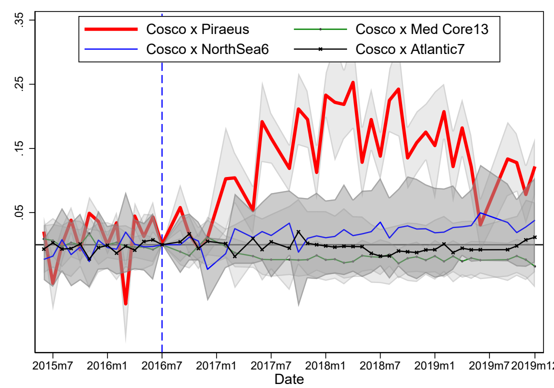
[22] The criteria used by Notteboom et al. (2019) to identify transhipment ports is that its transhipment incidence

Our results suggest that no region as a whole stands out as the sole loser from Piraeus' acquisition by COSCO. The point estimates even when negative for the other ports which have transhipment activity as their "raison d'être" like Piraeus are relatively small compared to the gain for Piraeus. In fact, the ports that seem to be losing out to the more systematic use of Piraeus by COSCO's giant ships are the major North Sea loading centers such as Antwerp, Rotterdam, Hamburg and Bremerhaven. These are so-called mixed ports as they are entry points to consumer markets but also traditionally have an important hub-and-spoke function in serving several countries, e.g. UK, Baltic and Scandinavia.[23]

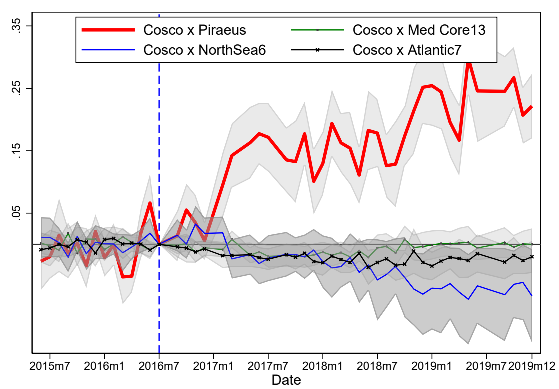
Figure 15: Triple Difference : COSCO in Piraeus and different ports groups (32 control ports)



(a) TEU<3000



(b) 3000≤TEU<10000



(c) TEU≥10000

Note: This figure plots the ranges of coefficients on the monthly interactions between COSCO × time and a dummy for Piraeus, the other Mediterranean sea ports, the North Sea ports and the Atlantic ports (the Baltic ports are hence used as the reference) from specifications of Table 6. The list of ports including in the 4 zones is reported in Table 2. The sample includes Piraeus and the 32 European "core" ports (other than Piraeus) which receive more than 50 monthly port calls over the period as listed in Table 2. The coefficients are estimated with respect to their respective values in July 2016 (which is absorbed in the ship-port fixed effect). The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO.

Note that Figure 15 also addresses a central issue in estimating our triple-difference term

in 2016 is above 65%.

[23]The most important category of ports are gateway ports which serve much more limited and specific geographic areas via feeders and handle modest transhipment volumes. This is the case of Mediterranean Sea ports like Genoa, La Spezia or Barcelona as well as UK ports, such as Southampton, Liverpool and Felixstowe, whose transhipment function, basically, is limited to their own country (Notteboom et al., 2019).

COSCO×Piraeus×Post$_{ym}$: the behavior of the control group before Piraeus' privatization shock as well as after. There is no apparent pre-trends for the ports belonging to the different regions. the results also seem to rule out the possibility of systematic negative spillover effects from the acquisition of Piraeus on other ports which would bias upward our key triple difference estimate. The results displayed in Figure 15 clearly show that the higher frequency of COSCO ships calling in Piraeus does not systematically come at the expenses of other ports: the sharp rise in the use of Piraeus is not mirrored in that of other ports.

7 Conclusion

The privatization of the port authority of Europe's ninth largest port by China's state-owned shipping company COSCO in July 2016 has fueled debates about the future of European trade infrastructure. The questions included the impact that the acquisition of a port by a shipping line has on container traffic not only in the privatized port but also in alternative and competing cargo destinations.

In this paper, we document the impact of the privatization of the Piraeus Port Authority using highly disaggregated data on container ship calls in European ports for 2015-2019. Using difference-in-difference estimates, we show that the Port of Piraeus exhibits a significant increase in traffic after 2016, consistent with the increase in its capacity since modernization and expansion works were undertaken. Our results are four-fold. First, the increase in traffic at Piraeus is skewed in favor of COSCO vessels whose probability of stopping at Piraeus increases significantly and sustainably. Non-COSCO vessels also increase their presence in Piraeus, but in the long run not in a way that is significantly different from their use of other ports. Second, not all COSCO vessels increase their use of Piraeus: the increase corresponds to vessels with a capacity of more than 3,000 twenty-foot equivalent units, and in particular the largest of them. Third, we do not identify any crowding out effect of COSCO's increased presence in Piraeus on other operators. These developments suggest that the port of Piraeus has become the transhipment port for COSCO, as both the larger vessels bringing in cargo and the medium-sized vessels likely handling supplies from neighboring ports increase their presence in the port. Our last finding relates to the possibility that more systematic stops of COSCO ships in Piraeus are at the expense of other European ports. We do not identify a decrease in the probability that ships will stop in other Mediterranean ports, even though most of the European ports specialized in transhipment and therefore the most directly involved in the transport of goods are located there. We also look at the evolution of COSCO's port calls in the Atlantic coast, the North Sea and the Baltic Sea to understand if the acquisition of the port of Piraeus by the Chinese operator has been accompanied by a reconfiguration of its port choices in Europe. We do not identify significant substitution movements with alternative ports, but we do find small decreases in the use of large COSCO vessels in the North Sea and Atlantic ports. We leave many paths open for future research especially as we need to better monitor vessels' routes and establish what is loaded on and unloaded from the ships during their stopovers.

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Appendix

A Eurostat ranking of ports

Table A-1: Annual Gross tonnage of vessels entering EU Ports

Port Name	Gross Tonnage 2007	Rank 2007	Gross Tonnage 2016	Rank 2016	Gross Tonnage 2019	Rank 2019
Rotterdam	96,956	1	129,598	1	123,723	2
Hamburg	79,421	2	94,206	4	96,956	3
Antwerp	68,935	3	117,336	2	124,235	1
Bremerhaven	54,684	4	98,080	3	70,800	6
Le Havre	53,755	5	73,006	6	69,835	7
Algeciras	50,989	6	76,940	5	73,981	4
Felixstowe	46,103	7	60,667	8	48,328	10
Gioia Tauro	38,783	8	40,787	13	38,755	12
Barcelona	34,060	9	42,311	12	52,142	9
Santa Cruz de Tenerife	29,559	10	4,153	19	5,030	19
Southampton	25,589	11	45,920	10	32,019	14
Marsaxlokk	24,709	12	72,944	7	60,978	8
Zeebrugge	20,178	13	5,720	18	9,327	17
Las Palmas	19,500	14	18,769	15	20,460	15
Genoa	18,726	15	43,683	11	44,842	11
Marseille	17,569	16	30,542	14	34,368	13
Livorno	16,147	17	10,037	16	13,945	16
Piraeus	**15,830**	**18**	**55,131**	**9**	**73,754**	**5**
Constanta	14,391	19	7,960	17	8,153	18
Valletta	14,200	20	2,425	20	1,239	20

Note: Source Eurostat.