Received: 13 January 2023 | Revised: 21 March 2023 | Accepted: 22 March 2023

DOI: 10.1111/roie.12675

SPECIAL ISSUE PAPER

WILEY

Sold to China: Container traffic in the Port of Piraeus

Pamina Koenig[1] | **Sandra Poncet**[2] | **Mathieu Sanch-Maritan**[3] | **Claude Duvallet**[4] | **Yoann Pigné**[4]

[1]University of Rouen & Paris School of Economics, France

[2]Paris School of Economics (University of Paris 1), France

[3]Université Jean Monnet Saint-Etienne, CNRS, Université Lyon 2, GATE Lyon Saint-Etienne, France

[4]LITIS, Université Le Havre Normandie, France

Correspondence
Pamina Koenig, University of Rouen & Paris School of Economics, France.
Email: pamina.koenig@psemail.eu

Funding information
ANR, Grant/Award Number: ANR-17-EURE-0001

Abstract

This article 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 its attractiveness and on that of competing ports for the ships of the various operators, and more particularly of COSCO. Difference-in-difference estimates suggest that the number of container ship calls to the Port of Piraeus has increased following its privatization, but that this increase in attractiveness corresponds mainly to vessels operated by COSCO with a capacity of more than 3000 twenty-foot equivalent units, and in particular to 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.

KEYWORDS

maritime traffic, ports, privatization

JEL CLASSIFICATION

F23, F61, L31

1 | INTRODUCTION

When COSCO Shipping Lines bought a majority stake in the Port of Piraeus in July 2016, what drew attention was not so much the privatization of the port, but the fact that the Chinese state-owned shipping company would now be the main decision-maker in the planning, management, and operation of the port authority of Greece's (and Europe's then) largest port (and 9th in Europe), as well as in the activities taking place in the port's various container terminals.

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, however the full privatization 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 company, ranked fourth among the world's largest shipping companies in terms of fleet capacity. Second, COSCO is a state-owned conglomerate recently created by the Chinese government in order to restructure its maritime activities. Third, it 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 article, we use real-time ship positions from vessel tracking systems to identify the ports where ships make stops prior and following July 2016. We analyze whether the transfer of ownership of the Port Authority of Piraeus has affected the number and composition of ships arriving at that port, potentially at the expense of other European ports. As COSCO, in close proximity to the Chinese government, holds significant importance, this development may indicate a strategic reorganization of China's trade routes with Europe, which could have substantial implications for other container transport companies[1] using the Greek port. This could also result in a diversion of traffic away from other European ports. We combine data on container[2] calls in European ports between 2015 and 2019 with information on the ships themselves (name, ID, operator, technical information such as length and capacity). We look at the extent to which the evolution of vessel traffic operated by the Chinese shipping company COSCO differs from other container carriers and analyze three issues related to the consequences of the privatization of the Port of Piraeus.

First, we want to understand whether the privatization of the Piraeus port authority and the massive investments made by the new owner COSCO have affected the relative attractiveness of the port. Our estimates investigate whether the improvement in infrastructure and the increase in tonnage received in Piraeus, which are visible in the overall statistics, have benefited all operators, that is, also COSCO's competitors. We provide a difference-in-differences estimate of how the evolution of the number of port calls in Piraeus differs from that in other comparable ports. Our estimates aim not only to take into account the specificity of the Port of Piraeus and the possibility that it leads to a pre-trend, but also the various developments that have taken place over the period in the other European ports. We verify that our results are not affected by the choice of the control group. We use three different sets of container ports to which we compare Piraeus: first, all the major European ports in our sample, second, a subsample of these major ports limited to ports handling more than 50 container ships per month as in Piraeus, and third, a group of 4 ports selected for their ability to replicate the traffic of the Port of Piraeus prior to its acquisition by

COSCO (synthetic group method). We identify a clear upward trajectory for maritime traffic in the Port of Piraeus. We then zoom in on this evolution by distinguishing the ships by their operator and we highlight that the increase in the number of calls received by Piraeus comes from an increased use of the port by the ships operated by COSCO. The number of calls by vessels operated by carriers other than COSCO increased after the privatization of Piraeus in line with the increase in the port's capacity, which suggests that the investments made in the port have benefited all shipping operators. This increase in traffic, however, is not different in the medium term from that of other ports, probably because the latter have themselves made investments and increased their capacity. In the end, the increase in the number of vessels calling at Piraeus is significant and sustained over the long term 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 is about whether ship calls in the Port of Piraeus have increased or decreased in frequency after the privatization of the port authority. We use the finest level of disaggregation at the ship level to study container traffic and pay particular attention to ship operators. We 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 use Piraeus more frequently. Estimates suggest a 5 percentage point increase in their probability of stopping in Piraeus after privatization. Controlling for the fact that vessels serve Asia over the sample period does not invalidate the results on Piraeus: COSCO's vessels increase their frequency of calls at Piraeus, even after controlling for their shipping service to the Chinese market. We then disentangle the effect by vessel size, distinguishing three categories in terms of capacity: feeders under 3000 TEUs, medium-sized vessels between 3000 and 10,000 TEUs, and vessels over 10,000 TEUs.[3] 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 vessels. This seems consistent with COSCO's decision to locate its transshipment hub for its European trade in Piraeus. Larger COSCO ships stop more consistently in Piraeus on their European voyages after privatization than before. Medium-sized ships also seem to make more stops in the Greek port to bring in or pick up goods that originate from or are destined for ports that cannot be reached by the larger ships. No effect is identified for the smaller COSCO vessels, probably due to the fact that their higher cost disqualifies them for transshipment operations to major por. Importantly, 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 (9th 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, and in particular whether COSCO ships' calls to Piraeus complement or replace calls to other European ports. In this way, we seek to understand whether the 2016 privatization has led to an overall reconfiguration of COSCO ships' port choices in Europe. 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 in Piraeus is, however, much greater than the decrease in the other European ports. 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 article is situated at the intersection of three strands of the literature: the global 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 investments 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 & Molina (2015) among others) as well as firm-level exports (Martincus & Blyde, 2013). Overall welfare gains have been identified (Allen & Arkolakis (2022) analyzes the effects of a reduction in domestic congestion costs) and compared to the corresponding costs (Ducruet, Juhász, Nagy, & Steinwender, 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, Dollar, and Micco (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, Freund, and Pham (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 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 article 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 (Gomtsyan, 2022; Marczinek, Maurer, & Rauch, 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: Brancaccio, Kalouptsidi, and Papageorgiou (2020) combines contracts between shipowners and exporters and detailed data on vessel movements to assess the role of endogenous trade costs on international trade, and Brancaccio, Kalouptsidi, and Papageorgiou (2022) 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, Moxnes, Ulltveit-Moe, and Zi (2019) assesses the impact of the 2016 Panama Canal expansion on trade costs, and March, Metcalfe, Tintoré, and Godley (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 article 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 provides 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

We present the key contextual elements of COSCO's acquisition of a majority stake in the Piraeus Port Authority in 2016 to show how the chosen model ("private ownership and private operations") is an unusual configuration in the European port industry. Indeed, the standard model for concession contracts signed for the operation and management of European terminals is the "public-port authority-private terminal operator" model. In this framework of devolution (and not privatization), the assets remain public, whatever the amount of the operations and risks transferred to private parties (Farrell, 2012; Zhu et al., 2019).

COSCO's involvement in Piraeus terminal operations and infrastructure construction began in 2009 following the standard model where the company did not have extensive powers within the port authority. The Piraeus Port Authority, originally named and controlled by the state, was transformed into a publicly traded company in 1999, with the Greek state holding 75% of the shares and a majority stake in the management (Psaraftis & 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.[4] 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.

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, proposed to sell 67% of the Piraeus Port Authority and launched an international tender. The sale was part of a broad privatization drive that included Athens International Airport and the Hellenic Telecommunications Organization and was demanded by Greece's international creditors (the European Commission, the European Central Bank and the International Monetary Fund) as a precondition for their financial assistance. The privatization program was intended to reduce public debt and attract investment in order to enhance the growth potential of the Greek economy. COSCO was the only company to submit a bid and acquired a majority stake (51% in the first phase) in the Piraeus Port Authority, committing to €350 million investment in the port over the next ten years (Pallis & Vaggelas, 2017). Although this agreement is part of a concession that ends in 2052 and has some limitations (the government can terminate the concession under certain conditions and the new owner cannot easily sell the asset), it is a master concession in which the concessionaire is allowed to reorganize or divide the port activity, the only thing that is not transferred to COSCO being the land (World Bank, 2003).

Since COSCO acquired a 51% stake in the Piraeus Port Authority in 2016, it has invested more than €600 million there. This investment has included the construction of a logistics center and the improvement and expansion of the Piraeus container Terminal 1. In addition, COSCO installed new cranes and other handling equipment, and undertook various other projects such as dredging the port to increase its capacity and efficiency (Piraeus Port Authority, 2016).

The literature is divided on the possibility that COSCO's decision to acquire the Port of Piraeus was motivated by both political and commercial considerations pushed by the Chinese government. On the one hand, COSCO appears to be a vehicle for China's geopolitical ambitions (Dokos, 2013; Van der Putten & Meijnders, 2015), and Chinese media portrays the COSCO Piraeus project as a key component of China's New Maritime Silk Road in Europe (Brinza, 2016; Zou, 2016). On the other hand, despite being a state-owned enterprise, COSCO appears focused on project profitability (Ma & Peverelli, 2019) while the Sino-Greek relationship regarding the Port of Piraeus remains primarily economic (Stroikos, 2022). Our article does not make any particular assumptions about the importance of geostrategic considerations in the choice of COSCO's acquisition of Piraeus, but by looking at the repercussions of this acquisition on COSCO's container traffic and that of competing operators, it aims at shedding light on the objectives sought, economic or otherwise.

3 | DATA AND DESCRIPTIVE STATISTICS

Let us now detail the maritime microdata on which we rely for the rest of the article. 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[5] 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 using 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.[6]

Our project accesses AIS data through an online sharing system to which we contribute. Various organizations, including maritime institutes, aerospace centers, and universities like ours, can capture ship signals within the proximity of an installed antenna. These signals are then shared

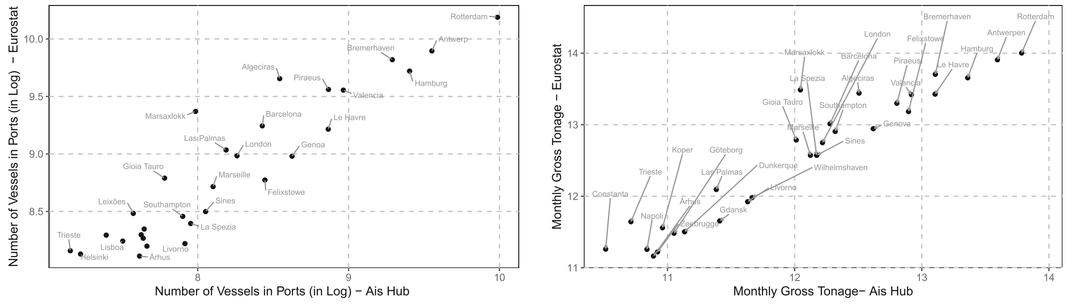


FIGURE 1 Number of vessels and gross tonnage in ports (in log)—Eurostat versus AIS Hub. Authors' computation using Eurostat and AISHub data. Eurostat data report, by port, the quarterly number of incoming vessels and the gross tonnage. Both are restricted to container vessels and to the 30 largest European 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 for 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.

on a website called AISHub, which enables all contributors to access the information within the entire network. Although our data offers the advantages of being low-cost and covering a long time period, it also has some limitations. The quality and spatial coverage of the data depend on the functioning of the antennas contributed by other parties. Our dataset begins in April 2015 and includes daily ship positions in areas covered by AISHub contributors, specifically ports and their surrounding regions.[7]

Our research concentrates on European ports, and as a result, we restrict our call data to European ports exclusively. Next, we combine this data with the Lloyd's list database, which includes detailed information about each ship, such as its name, size, operator, and type (such as barge or container). By utilizing this information, we are able to filter and retain only those ships designated as container ships in our final database. A comparison with Eurostat highlights that AISHub's data geographical coverage for Europe is excellent. The left panel of Figure 1 compares the total number of ships received by each port from our AISHub data with Eurostat data for the 30 largest European ports.

The values correspond to the total number of container ships calling in each port for the period July 2015–December 2019. The right panel of Figure 1 focuses on the gross tonnage handled in each port reported by the two databases. The correlation between the Eurostat and AISHub figures in the two panels is 0.93 and 0.94 respectively.

3.2 | Container ships and operators

The Lloyd's List reports around 6000 container ships in service around the world in 2015. About 5000 of these are observed in motion in our data in 2015, including about 2400 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 zoom on the four main shipping lines (MSC, Maersk, CMA-CGM, and

TABLE 1 Main operators in European ports (2015–2019).

Operator	Country	Number of ships	Share in %	Share by capacity (TEU) 3000–10,000 in %	Share by capacity (TEU) ≥ 10,000	Operator share in number of port calls (in %) Europe	Operator share in number of port calls (in %) 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.

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 3000 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 3000 and 10,000 TEUs) and New Panamax (or Neopanamax) starting at 10,000 TEUs.[8] 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.

3.3 | Ports

Since we seek to analyze the trajectory of the Port of Piraeus by comparing it to relatively comparable ports, we restrict our attention to ports that are defined by the European Commission as "Core Ports". Those ports are major nodes in the Trans-European Transport Network (TEN-T) that have high volumes of freight and passenger traffic and provide strategic connections between different modes of transport. 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 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 Appendix A.

Let us examine the trajectory of ports over time by analyzing the raw data. Figure 2 illustrates the monthly number of port calls for six distinct sets of ports during the sample period. The average monthly number of port calls in the 32 core ports specified in Table 2 increased from 200 port calls by container ships in July 2015 to 245 by the end of 2019. The Port of Piraeus, represented by the bold dotted line, starts at a relatively low level in July 2015, with 130 calls per month. Tarifffic increases quite sharply towards the beginning of 2017 with a gain of about 60 monthly port calls and remains at this average level of 190 monthly stops until the end of the sample in 2019.

Two other single ports are displayed on the figure as they are identified in Section 4 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 North sea. The latter appears on the upper side of Figure 2 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 and 150 port calls per month on average. While Piraeus jumps to a higher level from 2017, Genoa is very stable with a slight increase throughout the period. With these descriptive figures in mind, we now turn to estimates to study the particularity of the evolution of calls made in the Port of Piraeus as well as its composition in terms of ship operators.

4 | RELATIVE ATTRACTIVITY OF THE PIRAEUS

We use a difference-in-differences equation to study whether the total number of calls made in Piraeus evolves in a distinct way from those in other European ports after 2016. Our first estimates are based on the sample of 65 major European ports as well as on the sample restricted to 33 ports listed in Table 2. We use monthly data between July 2015 and December 2019 to contrast Piraeus' traffic relative to other ports (first difference), after its acquisition by COSCO compared to before

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 %) 1000 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
6	**Piraeus**	Greece	Med	177	16	4 865	41	24	90	36
7	Le Havre	France	Atlantic	176	2	6 423	53	27	89	42
8	Algeciras	Spain	Med	173	2	5 265	42	14	97	27
9	Genoa	Italy	Med	139	8	4 881	46	21	95	33
10	Felixstowe	UK	Atlantic	119	8	8 192	42	38	81	47
11	Barcelona	Spain	Med	118	2	4 674	42	19	97	32
12	Marsaxlokk	Malta	Med	103	5	5 672	41	21	93	42
13	London	UK	Atlantic	98	1	4 951	52	14	82	34
14	Marseille	France	Med	90	8	5 240	47	20	97	39
15	Sines	Portugal	Atlantic	82	0	5 745	61	21	90	34
16	La Spezia	Italy	Med	76	7	6 244	42	26	96	44
17	Gdynia	Poland	Baltic	71	5	1 526	31	0	23	4
18	Livorno	Italy	Med	70	3	3 770	58	0	93	24

TABLE 2 Continued

	Port name	Country	Zone	Av. monthly visits	Share of COSCO ship (%)	Av. TEU	Ships by capacity (in %) 1000 TEUs		Port calls share from ships	
							3–10	≥10	exited Europe	went to China
19	Southampton	UK	Atlantic	68	3	8 019	41	37	85	60
20	Venice	Italy	Med	68	10	1 725	22	0	88	12
21	Gioia Tauro	Italy	Med	66	0	6 357	55	23	91	40
22	Moerdijk	Netherlands	NorthSea	58	0	585	0	0	15	0
23	Aarhus	Denmark	Baltic	57	3	2 496	3	22	29	13
24	Ambarli	Turkey	Med	55	4	3 963	39	7	80	29
25	Lisbon	Portugal	Atlantic	55	2	1 726	29	0	74	9
26	Gothenburg	Sweden	Baltic	55	6	2 919	4	28	37	20
27	Liverpool	UK	Atlantic	54	0	1 483	30	0	51	7
28	Mersin	Turkey	Med	54	6	4 125	37	8	100	29
29	Kotka	Finland	Baltic	53	13	1 440	4	0	26	4
30	Helsinki	Finland	Baltic	53	9	1 190	2	0	24	6
31	Gdansk	Poland	Baltic	52	16	5 385	14	33	60	37
32	Koper	Slovenia	Med	51	14	3 624	20	21	94	32
33	Wilhelmshaven	Germany	NorthSea	51	8	7 113	27	33	68	38

Note: The bold was just to highlight the port of Piraeus, which is the port of interest in our study. 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, that is, 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.

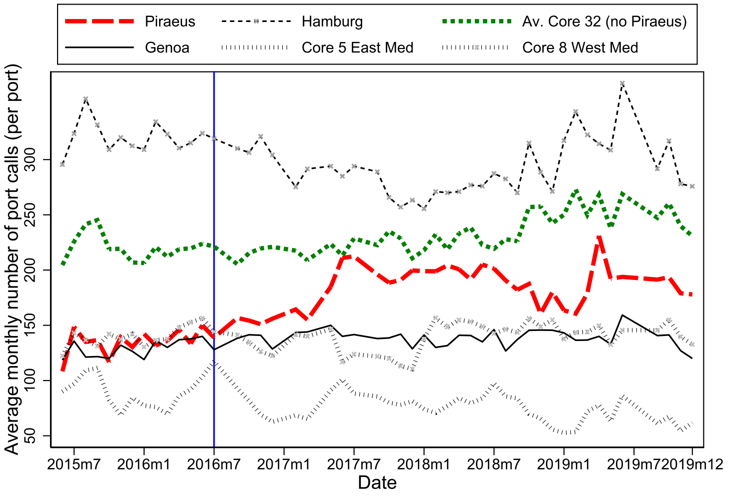


FIGURE 2 Evolution of number of port calls in Europe. Authors' computations using fully cellular containers covered in AIS data. Core 32 denotes the 32 European "core" ports (other than Piraeus) which receive more than 50 monthly port calls over the period as listed in Table 2. Genoa and Hamburg are the two ports identified as the most similar to Piraeus in terms of pre-privatization characteristics using the synthetic control methodology (Abadie & 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. [Colour figure can be viewed at wileyonlinelibrary.com]

(second difference). The estimated equation at the port level is as follows:

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

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 the dummy Post$_{ym}$, which equals 1 in each *year-month* from July 2016 onwards. Our identification strategy exploits the timing of privatization of the Port of Piraeus. While COSCO's decision to acquire the Port of Piraeus is obviously not random and certainly reflects the fact 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 to finalize. Our specification includes individual port fixed effects to account for the facts that the Port of Piraeus was already among the largest in Europe in June 2016 (it ranked 9th in terms of gross tonnage handled in 2016, see Appendix A), and for the fact that each port has an intrinsic potential. We are aware that different European ports that make up the control group have made investments over the period and that different developments have affected European maritime traffic as a whole. Our identification strategy controls for the general trend in European maritime capacity and traffic with period fixed effects and tests for the presence of a particular trend break for the Port of Piraeus. The period fixed effects also allow us to take into account the particularity of the period under study, which coincides with the deployment of highly concerted fiscal and monetary expansion programs in all European countries but also in China in order to overcome the 2008 crisis. 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. We ensure that our results do not reflect developments in some of the ports in the control group by checking that they are consistent for different samples.

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[9] and dynamic treatment effects[10] (Borusyak, Jaravel, & Spiess, 2021; Callaway & Sant'Anna, 2021; Sun & 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. The objective is not only to ensure the similarity of the traffic evolution in the other ports with that in Piraeus before the summer of 2016 but also to take into account that the capacity of the other ports did not remain constant after the summer of 2016. To verify that our results do not simply reflect the investments made in the other ports we select three alternative control groups to which we compare Piraeus and ensure that the findings are consistent. We use three distinct lists of ports to compose the control group: all 64 core ports of the European Commission's TENT-T network present in our sample, the subset of 32 ports receiving at least 50 container ships per month, and then the smaller group determined by the synthetic control group method for its ability to reproduce the pre-privatization traffic in Piraeus.

We begin by showing the estimated difference-in-differences coefficients obtained from the De Chaisemartin and d'Haultfoeuille (2020) estimator in Figure 3, using both the entire set of core ports and the version restricted to the 33 core ports (including Piraeus) which receive more than 50 port calls per month listed in Table 2. The coefficients are estimated by month. The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO. The coefficients to the left of this line can be interpreted as the placebo tests of the parallel trends assumption. Panels (a) and (b) report the results for 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 operators 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). They highlight that the previously identified increase in the number of boat stops in Piraeus after its privatization corresponds essentially to an increase in the number of boats operated by COSCO.

Panels (a) and (b) indicate an addition of approximately 20 COSCO-chartered vessel calls between spring 2017 and the end of 2019 compared to before the privatization of Piraeus. The increase in traffic by COSCO-vessels is continuous over the post-acquisition period. By contrast, the evolution of the number of port calls for non-COSCO operated ships in Panels (e) and (f) exhibits only a temporary relative rise: the relative increase that appears about 9 months after the change in ownership then dies out in 2018 and 2019.

The estimated pre-treatment coefficients (June 2015 to June 2016) in all panels of Figure 3 are alternately positive and negative around zero suggesting that the evolution of the number of ships received by the Port of Piraeus did not diverge significantly before its privatization from that received by the other ports. To strengthen our confidence in the absence of pre-trends, we replicate our results using the synthetic control method to construct the control group against which Piraeus is compared (Abadie & Gardeazabal, 2003; Abadie & Imbens, 2011). This method involves

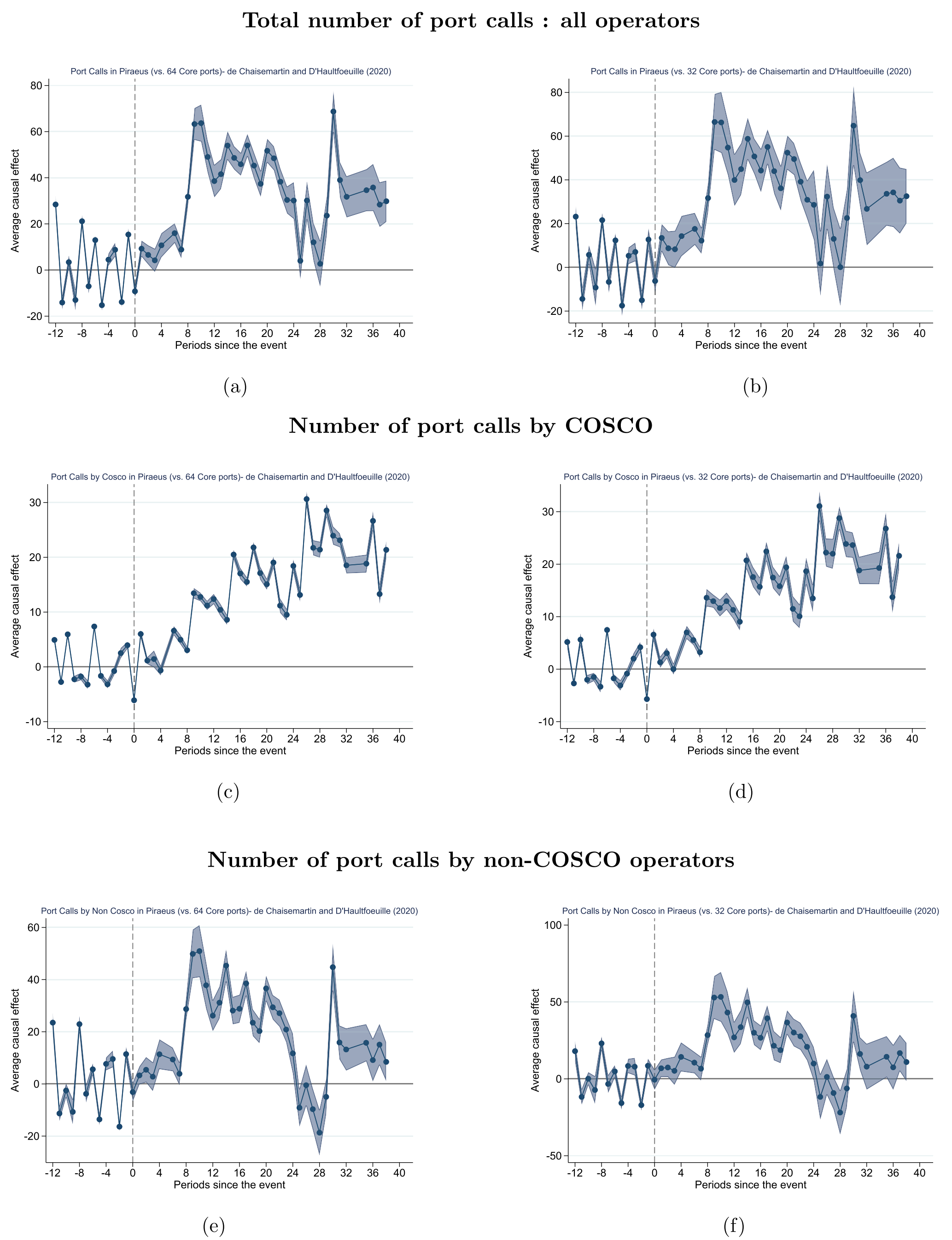
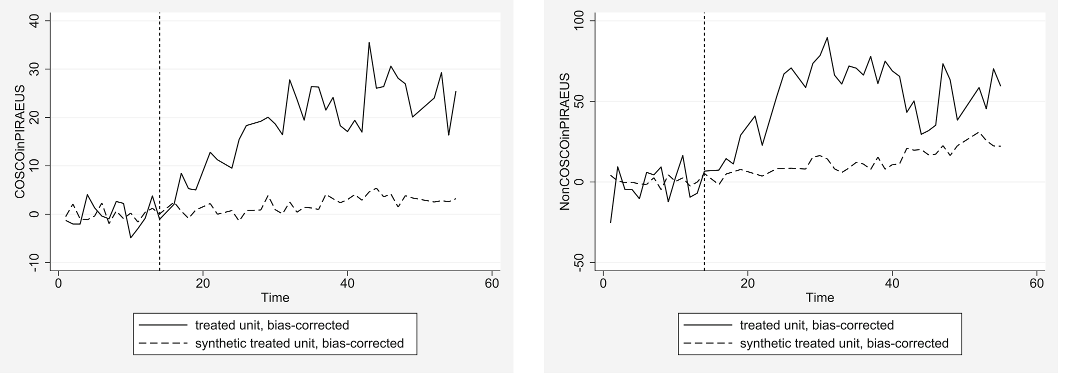


FIGURE 3 Port-level difference-in-differences (De Chaisemartin and d'Haultfoeuille (2020) estimator). Figures are generated by the *did_multiplegt* command (De Chaisemartin & d'Haultfoeuille, 2020). Standard errors are calculated using 100 bootstrap replications, clustered on the port level, 95% confidence intervals are shown. Figures plot 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 with consistent data in our AIS. In Panels (b), (d), and (f), the sample includes the 33 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. (a), (c), and (e) Piraeus vs. 64 Core ports. (b), (d), and (f) Piraeus vs. 32 Core ports. [Colour figure can be viewed at wileyonlinelibrary.com]



(a) (b)

FIGURE 4 Port-level difference-in-differences: Synthetic control method. Figures are 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%.

identifying the combination of ports that replicates the pre-treatment trajectory of Piraeus. 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. Genoa and Hamburg are always part of the group and account for at least three quarters of the total weight. The synthetic control group that matches Piraeus' evolution of the number of port calls for COSCO ships before July 2016 further includes the Finnish port of Kotka while that for the number of calls by non-COSCO vessels further includes the Mediterranean ports of La Spezia and Marsaxlokk.

Finally, the synthetic control method also recommends using the four ports of Genoa, Hamburg, La Spezia, and Marsaxlokk (however with different relative weights) to best replicate the total port traffic (all operators) in Piraeus before its privatization.[11] We will use these different control groups when we analyze the disaggregated ship-level data in the next section. In particular, we will check the robustness of the results when the sample is limited to calls in the Port of Piraeus as well as in these 4 ports identified by the synthetic control group method.

Panels (a) and (b) in Figure 4 report the estimated double-difference coefficients per month for the calls in the Port of Piraeus respectively for the vessels operated by COSCO and by the other companies. The differences between the two figures concern the average magnitude measured and the relative change from 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.

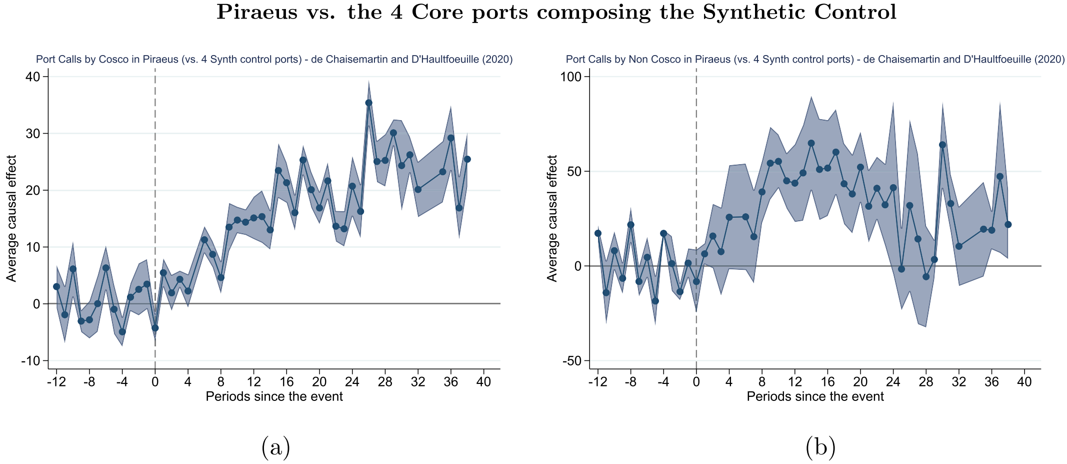


FIGURE 5 Port-level difference-in-differences (De Chaisemartin and d'Haultfoeuille (2020) estimator). Figures are generated by the *did_multiplegt* command (De Chaisemartin & d'Haultfoeuille, 2020). Standard errors are calculated using 100 bootstrap replications, clustered on the port level, 95% confidence intervals are shown. Figures plot 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 4. The dashed vertical line corresponds to July 2016 when Piraeus was purchased by COSCO. (a) COSCO, (b) Non-COSCO operators. [Colour figure can be viewed at wileyonlinelibrary.com]

The results are confirmed in Figure 5 which reports the coefficients obtained with the De Chaisemartin and d'Haultfoeuille (2020) estimator. Interestingly, the placebo estimators enclose 0 which is in support of the parallel trends assumption. Also, the results regarding post-acquisition effects are very consistent with those obtained with the larger control group sample and provide reassurance that the results are reliable. 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. It might be tempting to explain this attenuation by the investments made in various European ports to respond to the growth of international trade. Nevertheless, increases in port capacity in Europe affect the estimates obtained for COSCO vessels as well as those obtained for the vessels of other operators so that this explanation does not seem sufficient.

To complete our investigation of the specificity of the Port of Piraeus in COSCO's vessel choices, we replicate the difference-in-difference estimates for each of the 33 major ports by comparing the number of vessels they receive to that measured for their synthetic control group. The objective is to verify that the previously discussed result of increased use of the Port of Piraeus by vessels operated by the new owner of the port is not found in other European ports. Figure 6 displays the results for the ships operated by COSCO and Figure 7 presents those for other operators.

In both figures, the bold line represents the double difference coefficients for Piraeus discussed earlier. The other lines are the coefficients for the other ports. The continuous increase in the number of COSCO container ships calling in Piraeus after the summer of 2016 is not found in any of the other ports studied in Figure 6, suggesting that this result is truly specific to the Greek port.

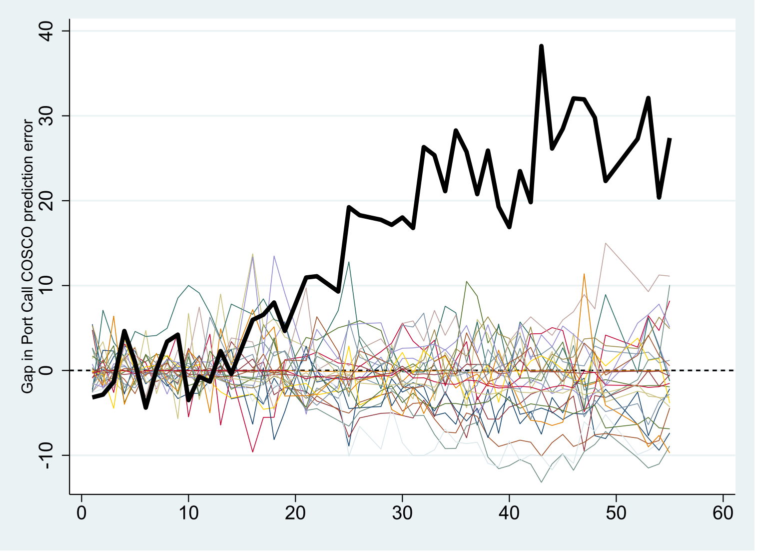


FIGURE 6 Synthetic control group for all ports, COSCO ships. The figure is generated by the allsynth command (Wiltshire, 2022). The matching variables are respectively the quarterly numbers of total ships and COSCO ships calling in each port before July 2016, the share of COSCO ships as well as information 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 in the corresponding synthetic control group. [Colour figure can be viewed at wileyonlinelibrary.com]

On the other hand, the evolution observed in Piraeus for vessels operated by other operators is also observed in several other ports, reinforcing the previous observation that the privatization of the Port of Piraeus has very specifically affected the position of Piraeus in the choice of European ports of call for COSCO vessels. We investigate in Section 6 whether this outcome for the Chinese shipping line is paralleled by modifications in its port choices elsewhere in Europe.

5 | SHIP-LEVEL PORT CHOICES

We now exploit the ship-level granularity of AIS to better understand the disproportionate increase in COSCO ship traffic in Piraeus after the privatization of the port. In particular, we investigate whether the magnitude of this COSCO bias depends on vessel size.

Three mechanisms may explain why the monthly number of vessels received by the Port of Piraeus has increased following its takeover by COSCO compared to before, in particular due to the increase in the number of vessels operated by COSCO. They include 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, and 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 hence 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. We would also like to know if other carriers turned away from the Port of Piraeus once it was majority controlled by COSCO.

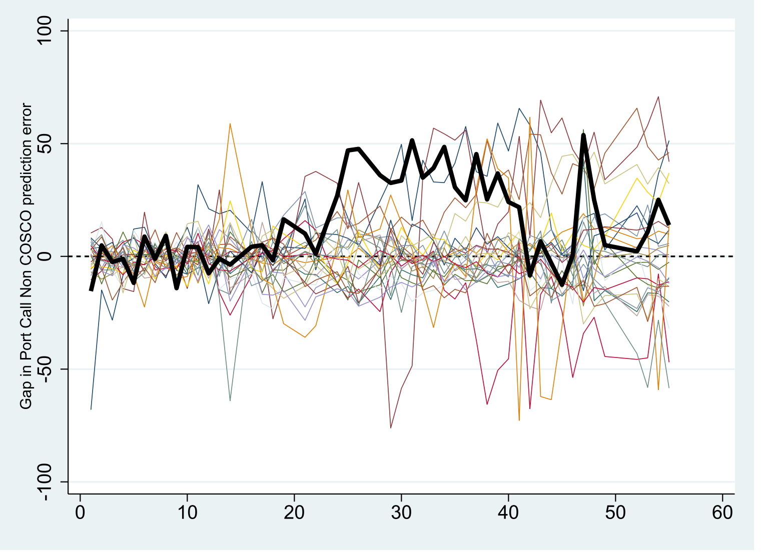


FIGURE 7 Synthetic control group for all ports, non-COSCO ships. The figure is generated by the allsynth command (Wiltshire, 2022). The matching variables are respectively the quarterly numbers of total ships and COSCO ships calling in each port before July 2016, the share of COSCO ships as well as information 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 in the corresponding synthetic control group. [Colour figure can be viewed at wileyonlinelibrary.com]

5.1 | The COSCO-bias

Our empirical approach is based on an explained variable which is a dummy indicating whether ship *s* 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 coded as zeros for this date. We estimate the following Equation (2) with a linear probability model:

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

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. The specific impact for COSCO-operated vessels is measured by the triple interaction term between the dummy denoting COSCO-operated ship and the double term Piraeus × Post_{ym}. In all specifications standard errors are 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.[12] The ship-level database includes a total of 144,835 calls, of which 109,027 are made in the 33 major ports listed in Table 2 by 1930 distinct ships, including 135 COSCO ships. The number of calls made in the Port of Piraeus amounts to 5420, of which 765 are by COSCO-operated vessels.

TABLE 3 Difference-in-differences in Piraeus for COSCO: Alternative control groups.

	Dummy 0/1 port call by Ship$_s$ in Port$_p$ at date t					
Explained variable	**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 4). 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 3 reports the results for Equation (2) before introducing the triple difference term. The port calls in the Port of Piraeus are compared to different control groups. Columns 1 and 2 use the 32 core European ports with more than 50 monthly port calls over the period listed in Table 2.[13] Columns 3 to 6 focus on the restricted sample where port calls in Piraeus are compared with those in the four ports with similar number of port calls before July 2016 as identified when applying the synthetic control method on the total number of ports calls (see Panel (b) of Figure 4). The sample is much smaller and includes 117,830 observations corresponding to 23,566 port calls in Piraeus (5420), Genoa (4343), Hamburg (9210), La Spezia (2442), and Marsaxlokk (2151).

The odd-numbered columns do not include ship-port fixed effects (ν_{sp}) and report coefficients for both the Piraeus dummy and the interaction between Piraeus and Post$_{ym}$. 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 variable is positive and significant when the fullest sample is used, it is indistinguishable from zero when the sample is restricted to the most similar ports. This result is reassuring that the restricted control group based on the synthetic control group method 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 the privatization of Piraeus in the probability of calling at Piraeus compared to the difference before/after calling at another port in the control group. The interaction term attracts a positive and significant coefficient in the comprehensive sample (column 2) as well as in the restrictive one (column 4). The result of a relative rise in the propensity of a given ship to stop in Piraeus after it got acquired by COSCO is consistent with findings obtained using the aggregate data in Section 4. The magnitudes corresponding to the results of columns 4 and 6 are significant: the probability of calling at Piraeus (compared to other ports) is on average 5% higher after the privatization of Piraeus (July 2016–December 2019) than before (June 2015–June 2016).

Table 4 builds on the specification of columns 2 and 4 of Table 3 and includes the triple difference term COSCO × Piraeus × Post to investigate whether this rise mostly relates to COSCO ships as suggested by the aggregate results from Section 4. 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 reflects 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 dummies for the year 2016 to separate the period before the privatization (January–June) from that after (August–December). 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 control ports considered, the results confirm a distinct increase in the propensity of COSCO vessels to use Piraeus after its privatization.

The estimated coefficient before the triple difference term is in line with the raw data which indicate that the average probability of a COSCO ship stopping in Piraeus while in Europe increases from 15% to 45% over the period.

It is reassuring that there is no significant pre-trends when in columns (4) to (6) the control group is made of the 4 ports identified by the synthetic control group approach (Genoa, Hamburg, La Spezia, and Marsaxlokk). The yearly double-difference and triple-difference estimates in column 6 reveal that the timing of the increase corresponds to that of the privatization of the Port of Piraeus and refutes the idea that there is already an earlier divergence: none of the interactions between COSCO × Piraeus and the period dummies before July 2016 are significant. The lack of significance for all interaction terms involving the dummy variable designating vessels serving China in column 6 suggests that it is being operated by COSCO and not serving the Chinese market that contributes to the distinctive shift in the choice of Piraeus by COSCO ships.

Figure 8 displays the monthly estimates for the double interaction Piraeus × $Post_{ym}$ as well as the triple interactions for COSCO×Piraeus×$Post_{ym}$ and Ship visited China×Piraeus×$Post_{ym}$ over the whole period. The coefficients are estimated with respect to their respective values in July 2016 (which is absorbed in the ship-port fixed effect). They highlight that the higher frequency of COSCO ships calling in Piraeus does not merely reflect that these ships are traveling on routes which serve the Chinese market. The results confirm that the increase in traffic 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.

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. We use the number of twenty-foot equivalent units (TEU) of ships and distinguish the various container ships into feeders (below 3000 TEUs), Panamax and Post Panamax (capacity between 3000 and 10,000 TEUs) and New Panamax (or Neopanamax) starting at 10,000 TEUs.[14]

Table 5 reports the results on the COSCO bias after the privatization of Piraeus for different ship capacity. The top panel corresponds to the specification of Equation (2). Columns 1 through 4 are for the sample of 33 ports while columns 5 through 8 are for the limited sample of synthetic

TABLE 4 Double and triple differences for Piraeus: COSCO, non-COSCO and trips to China.

	Dummy port call by Ship$_s$ in Port$_p$ at date t					
Explained variable	**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 × January-June 2016			-0.005[a]			−0.016
			(0.001)			(0.014)
Piraeus × August-December 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 × January–June 2016			0.022[a]			0.035
			(0.004)			(0.040)
COSCO × Piraeus × August–December 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)

TABLE 4 Continued

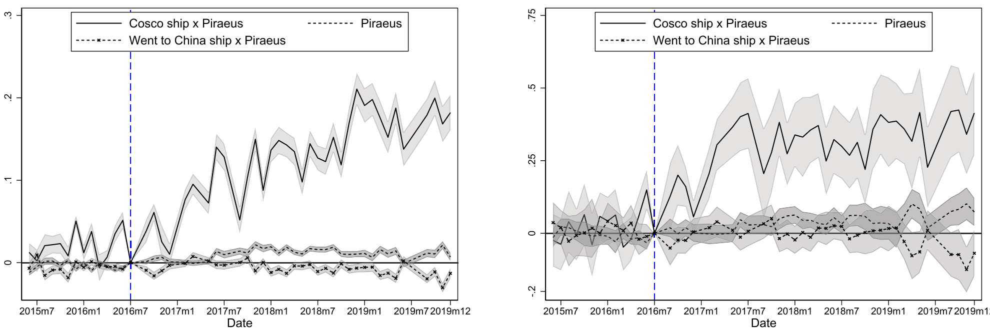
Explained variable	**Dummy port call by $Ship_s$ in $Port_p$ at date *t*** 1	2	3	4	5	6
Control ports	**32 core ports**			**Synth control group: 4 ports**		
Ship visited China × Piraeus × Post		−0.004			−0.020	
		(0.002)			(0.032)	
Ship visited China × Piraeus × 2015			−0.006[c]			0.005
			(0.003)			(0.037)
Ship visited China × Piraeus × January–June 2016			−0.004[c]			0.015
			(0.002)			(0.028)
Ship visited China × Piraeus × August–December 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 4). The control group is made of Genoa, Hamburg, La Spezia, and Marsaxlokk.

control group ports. Columns 1 and 5 reproduce columns 1 and 4 of Table 4 respectively. The bottom panel adds port-year-month fixed effects that control for time-varying port characteristics and absorb the interaction term Piraeus × Post.

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, that is, vessels with a capacity of less than 3000 TEUs. Columns 3 and 7 consider Panamax and Post Panamax with capacities between 3000 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 following its acquisition by COSCO, the Port of Piraeus has become a more systematic stop for the Chinese operator's large container ships. The increase in the propensity of COSCO vessels to stop at Piraeus after its privatization does not concern feeders, that is, small vessels that collect containers from ports where large vessels do not go and



(a) (b)

FIGURE 8 Piraeus difference-in-differences specific to COSCO ships. 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 4). 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. (a) Piraeus versus the 32 core ports, (b) Piraeus versus the 4 core ports composing the synthetic control. [Colour figure can be viewed at wileyonlinelibrary.com]

transport them to central container terminals, such as Piraeus, where they are loaded on larger vessels. COSCO's share in the operations of this type of vessel in the Port of Piraeus does not change as a result of privatization. While there is an increase in stops by feeders in Piraeus after its privatization, this is not particularly marked for COSCO vessels. This seems consistent with the fact that the feeders that bring the containers that are then loaded onto COSCO's large vessels to Piraeus or that pick them up there to bring them to smaller ports are not systematically operated by COSCO.

The relative rise in the propensity of the large COSCO-operated container ships to stop in Piraeus compared to the other European ports is especially marked 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 make up the control group.

Figure 9 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 3000 and 10,000 TEUs (Panel b) and from New Panamax vessels above 10,000 TEUs (Panel c). These contrasting results probably reflect the smaller share of feeders and the over-representation of larger vessels in the COSCO fleet operating in Europe as indicated in Table 1.

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

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	< 3000	3000–10,000	≥ 10,000	All	< 3000	3000–10,000	≥ 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
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 4). The control group is made of Genoa, Hamburg, La Spezia, and Marsaxlokk. The sample in columns 3 and 7 includes ships with capacity between 3000 and 10,000 TEUs. The sample in columns 4 and 8 includes ships with capacity above 10,000 TEUs.

at the pattern of use of Piraeus by operators other than COSCO. Figures 10–12 duplicate our triple-difference results from Figure 9 for the six main operators listed in Table 1. These include MSC, Maersk, CMA-CGM, Hapag-Lloyd, Yang Ming, and Evergreen.[15]

The six 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 10–12 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 12).[16] The Taiwanese company was part of an alliance with COSCO until April 2016 (this alliance also included Evergreen and K Line). In April 2016, as described in Figure 13 the four existing alliances were reshuffled into 3: (1)

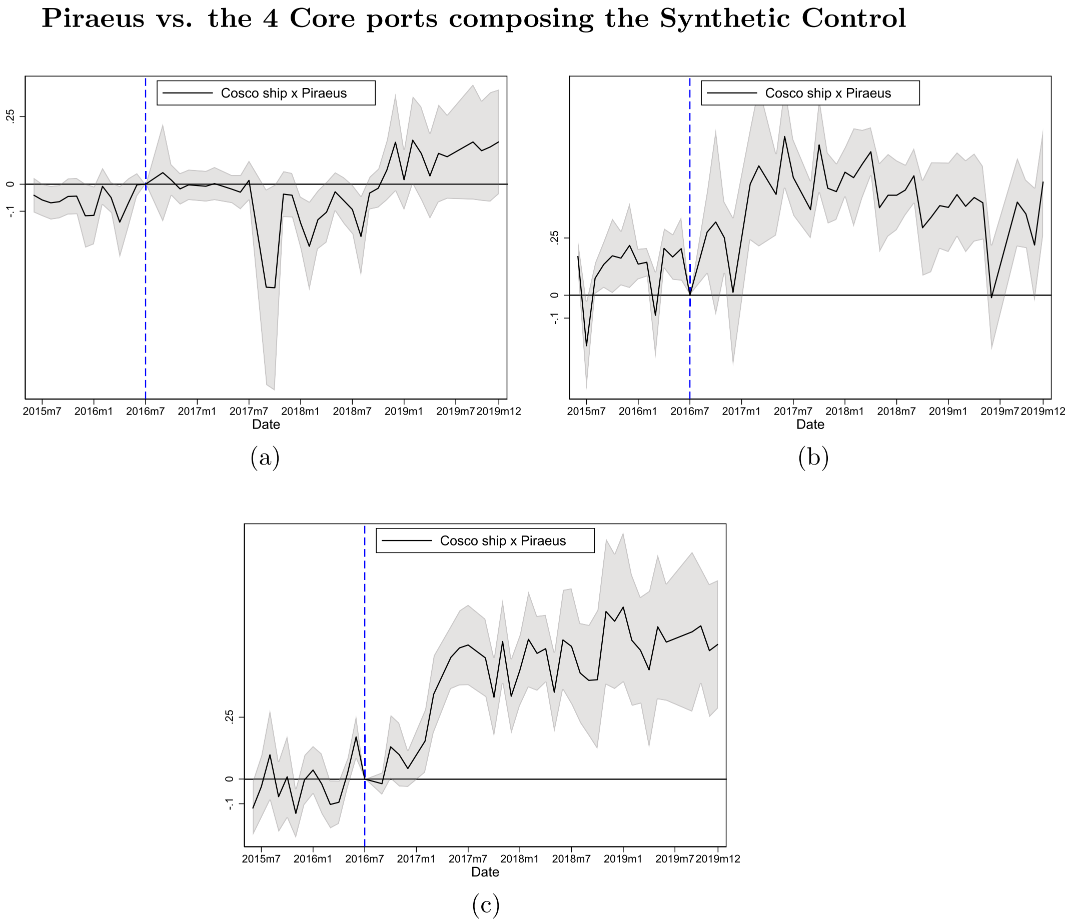


FIGURE 9 Triple difference for COSCO ships in Piraeus: Different ship capacity. This figure plots the ranges of coefficients on the monthly interactions for Piraeus×COSCO in a specification similar to that of columns 6 to 8 specification of Table 5, where Piraeus is compared to Genoa, Hamburg, La Spezia, and Marsaxlokk (the four ports making up the synthetic control unit). The sample includes respectively ships with a capacity below 3000 TEUs in Panel (a), with a capacity between 3000 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. (a) Ships with capacity < 3000 TEUs, (b) Ships with capacity 3000–10,000 TEUs, (c) Ships with capacity ≥ 10,000 TEUs. [Colour figure can be viewed at wileyonlinelibrary.com]

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. It is possible that the drop in the propensity of large Yang Ming ships to stop in Piraeus corresponds to a reorganization of the routes operated by the Taiwanese company following its change of alliance and not to a change in the conditions for receiving its ships in Piraeus.

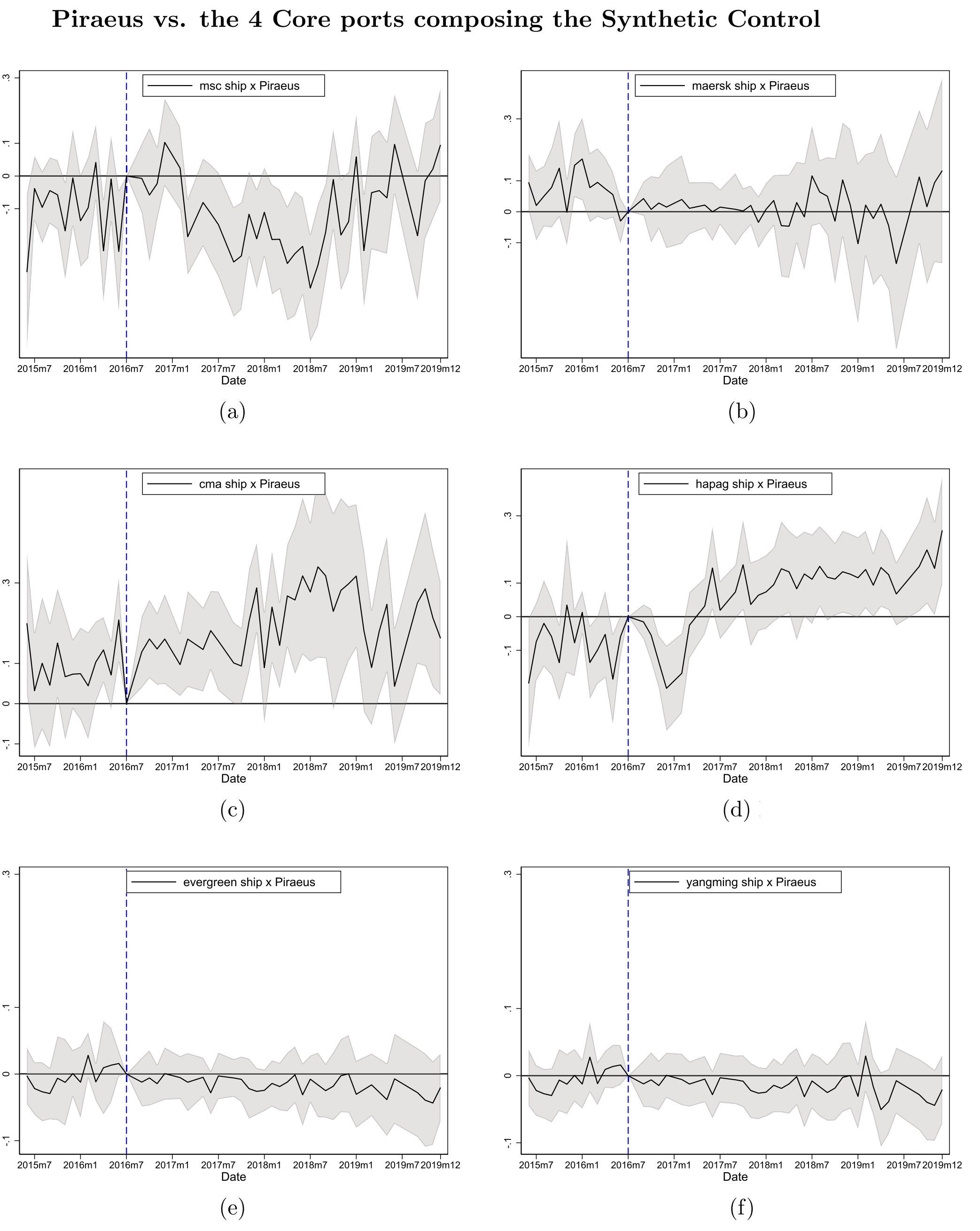


FIGURE 10 Triple difference: Piraeus × Specific operator (ship capacity < 3000 TEUs). This figure plots the ranges of coefficients on the monthly interactions between a ship operator and Piraeus in a specification similar to the column 6 of Table 5 applied to a sample from which COSCO ships are removed. Only ships with capacity below 3000 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. (a) MSC, (b) Maersk, (c) CMA-CGM, (d) Hapag, (e) Evergreen, (f) Yang Ming. [Colour figure can be viewed at wileyonlinelibrary.com]

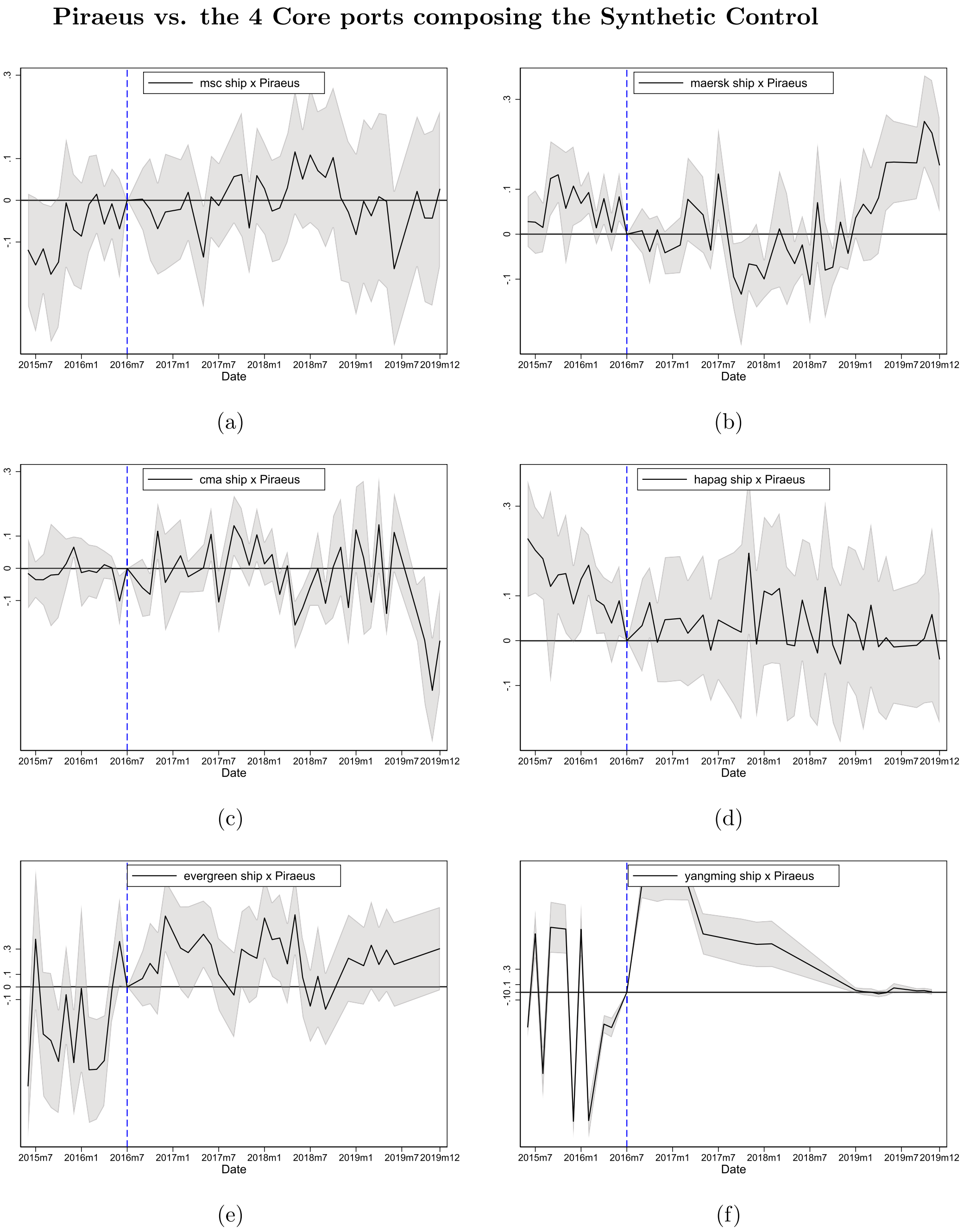


FIGURE 11 Triple difference: Piraeus × Specific operator (ship capacity 3000–10,000 TEUs). This figure plots the ranges of coefficients on the monthly interactions between a ship operator and Piraeus in a specification similar to the column 7 of Table 5 applied to a sample from which COSCO ships are removed. Only ships with capacity between 3000 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. (a) MSC, (b) Maersk, (c) CMA-CGM, (d) Hapag, (e) Evergreen, (f) Yang Ming. [Colour figure can be viewed at wileyonlinelibrary.com]

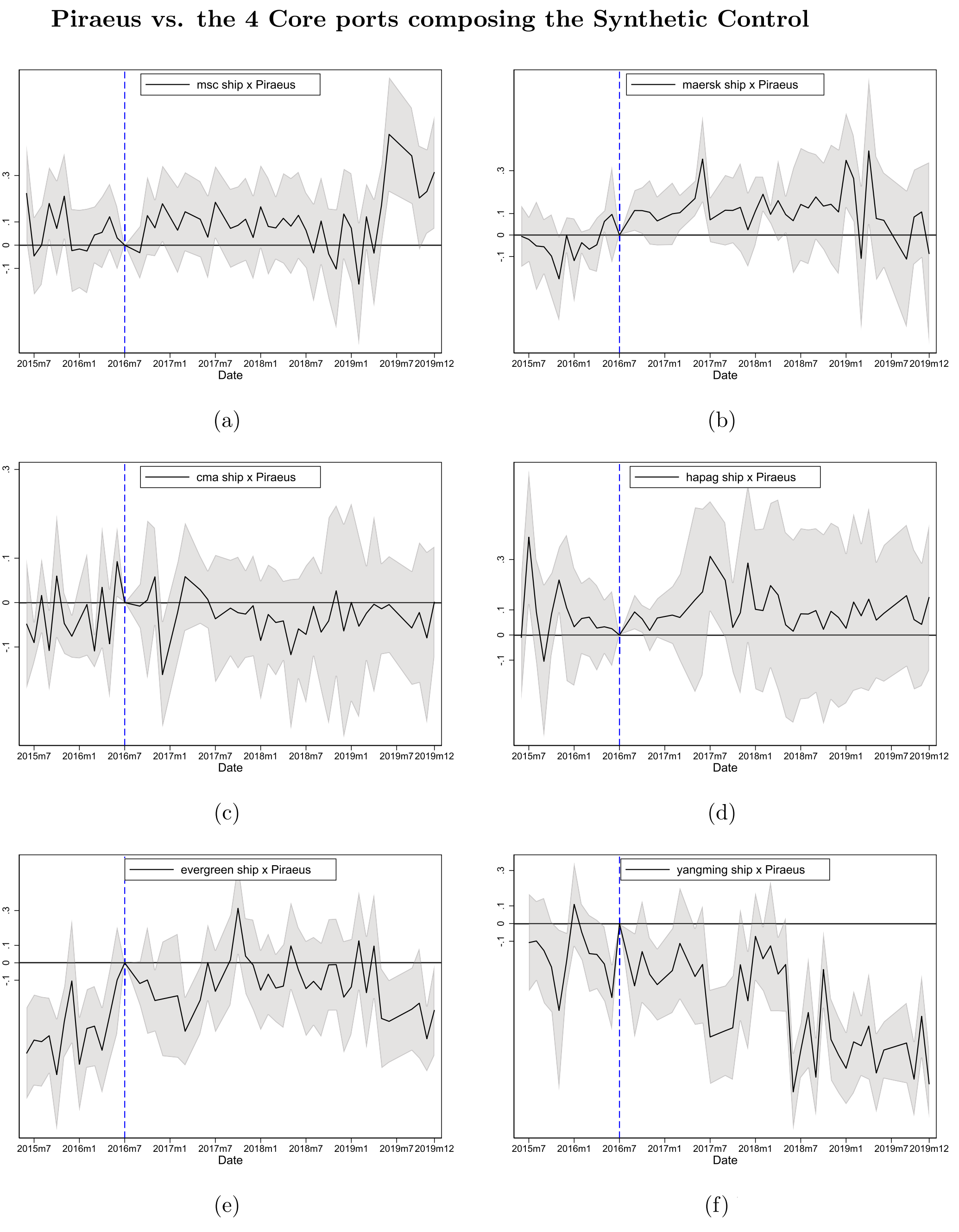


FIGURE 12 Triple difference: Piraeus × Specific operator (capacity ≥ 10,000 TEUs). This figure plots the ranges of coefficients on the monthly interactions between a ship operator and Piraeus in a specification similar to the column 8 of Table 5 applied to a sample from which COSCO ships are removed. 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. (a) MSC: (b) Maersk, (c) CMA-CGM, (d) Hapag, (e) Evergreen, (f) Yang Ming. [Colour figure can be viewed at wileyonlinelibrary.com]

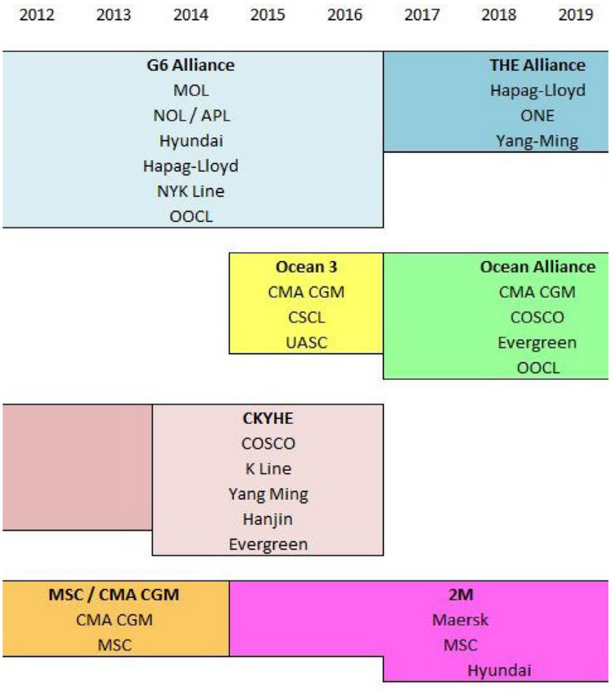


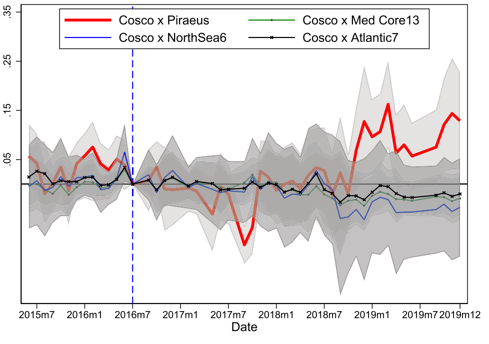
FIGURE 13 Operator alliances. *Source*: Wikipedia. [Colour figure can be viewed at wileyonlinelibrary.com]

6 | INVESTIGATING PORT SUBSTITUTION

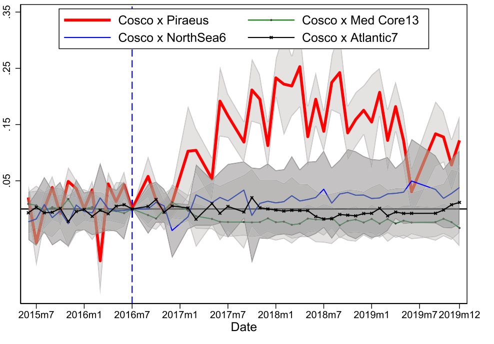
Our third question is whether the greater propensity of COSCO vessels to call at Piraeus is in addition to or instead of calls at other ports. This question echoes the more general question of the purpose of the acquisition of the Port of Piraeus by COSCO. Indeed, if the intention of the Chinese operator is to use Piraeus as the main hub for the organization of its activities in Europe, then some of its ships that previously called at other European ports should, after privatization, call at Piraeus. Does this add or substitute to calls in other ports? The possibility of a substitution of activities between Piraeus and other European ports is all the more credible as the arrival of Chinese capital in the Piraeus port authority has not only strengthened transshipment activities but also promoted better connectivity and the development of the Greek port's hinterland.

From an econometric point of view, the substitution scenario obviously challenges the implicit assumption underlying the difference-in-differences estimator, namely the assumption of no impact for the control group. To study this, we use the extended sample of 32 European "core" ports (other than Piraeus) that receive more than 50 monthly port calls over the period as listed in Table 2. Concretely, we investigate whether at the same time that COSCO ships stop more in Piraeus they stop less in the other main European ports. This amounts to estimating the coefficient of the interaction of the COSCO dummy after July 2016 not with a dummy for the Port of Piraeus but with a dummy for another port.

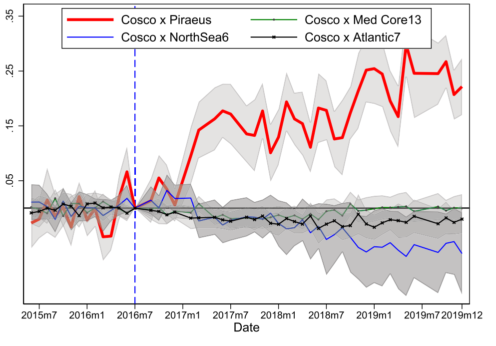
We take into consideration the geographical location of ports and investigate a regional substitution effect whereby the rise of Piraeus would divert ships from ports of a specific sub-region. Since Piraeus is located in the Mediterranean it might seem possible that the COSCO ships that increasingly stop in Piraeus after its privatization no longer stop in other Mediterranean ports



(a)



(b)



(c)

FIGURE 14 Triple difference: COSCO in Piraeus and different ports groups (32 control ports). This figure plots the ranges of coefficients on the monthly interactions between COSCO and four dummies: a dummy for Piraeus, a dummy for the other Mediterranean sea ports, a dummy for the North Sea ports and a dummy for the Atlantic ports (the Baltic ports are hence used as the reference) from specifications of Table 5. 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) with 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. (a) TEU<3000, (b) 3000 ≤ TEU<10,000, (c) TEU≥10,000. [Colour figure can be viewed at wileyonlinelibrary.com]

where they used to stop. It is also interesting to see how the rise of Piraeus challenges the hegemony of the North Sea ports, which occupy the top four places in the ranking of European ports. To investigate such a pattern, we use the 4 zones referred to in Table 2, that is, Baltic, North Sea, Atlantic, and Mediterranean Sea.[17] 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 × Post and four dummies, denoting respectively Piraeus, the other Mediterranean sea ports, the North Sea ports and the Atlantic ports.

Results are reported in Figure 14 where the three panels look at ships of different capacity: less than 3000 TEUs in Panel (a), between 3000 and 10,000 TEUs in Panel (b), and above 10,000 TEUs in Panel (c). They correspond to the specifications in columns 2 to 4 of Table 5.

Note that Figure 14 also addresses a central issue in estimating our triple-difference term COSCO × Piraeus $\times Post_{ym}$: 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 confirm previous findings that the regional organization of feeders operated by COSCO has not been affected by the acquisition of Piraeus by the Chinese company (Panel (a)). Our results also indicate a relative stability in the propensity of COSCO vessels to stop at ports in the three major areas (relative to the fourth area in the Baltic Sea) for intermediate size vessels (Panel (b)) and large vessels (Panel (c)). The increase in COSCO vessels' use of Piraeus is not accompanied by a large significant decrease elsewhere. Notably no region as a whole stands out as the sole loser from Piraeus' acquisition by COSCO. The low value and insignificance of the coefficients for the Mediterranean ports suggest 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 attractivness of the ports' hinterland (Ducruet & Notteboom, 2012).[18] In our sample of the 32 core ports, 5 ports are identified as transhipment hubs by Notteboom et al. (2019): they consist of three Mediterranean ports (Algeciras, Gioia Tauro, and Marsaxlokk) as well as Sines (Portugal) and Gdansk (Poland).[19]

In fact, the ports that seem to be losing the most from 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.[20] 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, for example, UK, Baltic and Scandinavia.[21] Coefficients are most negative for vessels with a capacity exceeding 10,000 TEUs (Panel (c)) but the negative estimates are relatively small compared to the positive estimates for Piraeus.

The estimated impact for intermediate-sized vessels (between 3000 and 10,000 TEV) in these same ports is also positive. It seems possible that the privatization of Piraeus has imposed the Greek port as a hub for COSCO's European operations: some containers brought in by New Panamax COSCO ships above 10,000 TEUs no longer systematically arrive directly in the major ports of Western Europe but are partly dispatched during the call at Piraeus on board smaller COSCO ships that make the connection between Piraeus and these major European ports.

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 14 clearly show that the higher frequency of COSCO ships calling in Piraeus does not systematically come at the expense of other ports: the strong increase in the use of Piraeus does not translate into a decrease for the other ports.

7 | CONCLUSION

This article examines the impact of the privatization of the port authority of Europe's ninth largest port, Piraeus, which was acquired by the Chinese state-owned shipping company COSCO in July 2016. Our difference-in-difference estimates show a significant increase in traffic in the Port of Piraeus after privatization in connection with the increase in its capacity allowed by the modernization and expansion work undertaken by its new investor. They also suggest effects in four specific areas. First, the increase in traffic in the Port of Piraeus is biased in favor of COSCO vessels, whose probability of stopping in Piraeus increases significantly and sustainably. Non-COSCO ships increase their frequency of stops in Piraeus, but not in a way that is significantly different in the long run from that in other European ports. Second, not all COSCO vessels are increasing their use of Piraeus: this is only the case for vessels with a capacity of more than 3000 twenty-foot equivalent units, and particularly for the largest of them. These developments suggest that the Port of Piraeus has become COSCO's central transshipment port, with an increase in the use of its large vessels engaged in intercontinental trade as well as those of intermediate size providing collection and re-routing to neighboring ports that may not be able to accommodate the larger vessels. Third, we do not identify any crowding out effect of COSCO's increased presence in Piraeus on other operators in that 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 any decrease in the likelihood that COSCO vessels stop at other Mediterranean ports, even though they are among the most specialized in transshipment and therefore compete most directly with Piraeus. We also examine the evolution of COSCO's calls on the Atlantic coast and in the North Sea to understand whether the acquisition of the Port of Piraeus by the Chinese operator has been accompanied by a reconfiguration of the routes taken by its ships in Europe. We do not identify significant substitution movements with alternative ports, but we do find slight decreases in the use of COSCO's large vessels in the North Sea.

We leave many avenues of research open, insofar as a detailed understanding of the reconfigurations at work requires taking into account the itineraries of the various ships and determining what is loaded and unloaded from the ships during their stops. It would also seem appropriate to verify, on the basis of more recent data, whether the results obtained are confirmed over the long term and are therefore not solely due to the importance of the concerted fiscal and monetary expansion programs at the global level that characterizes the period studied.

ACKNOWLEDGMENTS

We received funding from ANR, the Grant ANR-17-EURE-0001 and the Cepremap for their support. This work is also supported by the Réseau d'Initiative Normande funded by the Normandie Region. We thank Pierre Cariou, Nigel Pusey, as well as participants at the Kiel Institute for World Economics, the Vienna workshop for Regional Economics, the GSIE seminar, the International workshop on China and Global Economy, and the FAERE conference for useful comments.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Pamina Koenig https://orcid.org/0000-0002-2000-7301
Sandra Poncet https://orcid.org/0000-0001-8714-4610
Mathieu Sanch-Maritan https://orcid.org/0000-0002-0410-8479
Claude Duvallet https://orcid.org/0000-0002-8934-1498
Yoann Pigné https://orcid.org/0000-0002-3570-7490

ENDNOTES

[1] Throughout the article we equivalently use the words *operator*, *carrier shipping line* or *charterer* to refer to container transport companies.

[2] We define container ships as those named *fully-cellular container ships* in the Lloyd's list. This excludes cargo vessels that are equipped for both containers and vehicles and that might behave differently because they need suitable facilities to unload both types of cargo. This is a very small minority of vessels in our database, called "container/Ro-Ro cargo ships" in the Lloyd's list.

[3] 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.

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

[5] This includes all ships above 300 gross tonnage engaged on international voyages as well as cargo ships above 500 gross tonnage not engaged in international voyages.

[6] Heiland et al. (2019) use satellite and port calls data for the calendar year 2016 while Ganapati, Wong, and Ziv (2021) exploit vessel positions based on port calls from April to October 2014.

[7] The AISHub system generates a massive amount of data (signal frequency increases with ship speed) that needs to be cleaned. Cleaning consists of getting rid of duplicate data such as multiple occurrences of a given ship in a given port on a given day as well as removing periods where our antenna did not work properly.

[8] The largest category, the ultra large container vessel (ULCV) have a capacity of 14,501 TEUs and higher.

[9] 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 & d'Haultfoeuille, 2020)

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

[11] 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%).

[12] 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 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.

[13] The size of the sample is hence $3{,}597{,}891 = 109{,}027 \times 33$.

[14] The largest boats are called ULCV when their capacity exceeds 14,501 TEUs.

[15] We do not look at Ocean since it made its debut in 2016 as a joint venture between NYK (Nippon Yusen Kaisha), MOL (Mitsui O.S.K. Lines) and K Line (Kawasaki Kisen Kaisha). It was officially created in July 2017.

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

[17] 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.

[18] According to Notteboom, Parola, and Satta (2019), up to 85% of Piraeus' activities are dedicated to transhipment.

[19] The criteria used by Notteboom et al. (2019) to identify transhipment ports is that its transhipment incidence in 2016 is above 65%.

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

[21] 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).

REFERENCES

Abadie, A., & Gardeazabal, J. (2003). The economic costs of conflict: A case study of the Basque country. *American Economic Review*, *93*, 113–132.

Abadie, A., & Imbens, G. W. (2011). Bias-corrected matching estimators for average treatment effects. *Journal of Business & Economic Statistics*, *29*(1), 1–11.

Abadie, A., & L'Hour, J. (2021). A penalized synthetic control estimator for disaggregated data. *Journal of Business & Economic Statistics*, *116*(536), 1817–1834.

Allen, T., & Arkolakis, C. (2022). The welfare effects of transportation infrastructure improvements. *The Review of Economic Studies*, *89*(6), 2911–2957.

Blonigen, B. A., & Wilson, W. W. (2008). Port efficiency and trade flows. *Review of International Economics*, *16*(1), 21–36.

Blyde, J., & Molina, D. (2015). Logistic infrastructure and the international location of fragmented production. *Journal of International Economics*, *95*(2), 319–332.

Borusyak, K., Jaravel, X., & Spiess, J. (2021). *Revisiting event study designs: Robust and efficient estimation*.

Brancaccio, G., Kalouptsidi, M., & Papageorgiou, T. (2022). The impact of oil prices on world trade. *Review of International Economics,* 1–20.

Brancaccio, G., Kalouptsidi, M., & Papageorgiou, T. (2020). Geography, transportation, and endogenous trade costs. *Econometrica*, *88*(2), 657–691.

Brinza, A. (2016). How a Greek port became a Chinese 'dragon head'. *The Diplomat*, *25*, 2016–2017.

Callaway, B., & Sant'Anna, P. H. (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics*, *225*(2), 200–230.

Clark, X., Dollar, D., & Micco, A. (2004). Port efficiency, maritime transport costs, and bilateral trade. *Journal of development economics*, *75*(2), 417–450.

De Chaisemartin, C., & d'Haultfoeuille, X. (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *American Economic Review*, *110*(9), 2964–2996.

Djankov, S., Freund, C., & Pham, C. S. (2010). Trading on time. *The review of Economics and Statistics*, *92*(1), 166–173.

Dokos, T. (2013). *The geopolitical implications of Sino-Greek relations*. Clingendael article 10.

Ducruet, C., Juhász, R., Nagy, D. K., & Steinwender, C. (2020). *All aboard: The effects of port development* (Technical report). National Bureau of Economic Research.

Ducruet, C., & Notteboom, T. E. (2012). The worldwide maritime network of container shipping: spatial structure and regional dynamics. *Global Networks*, *12*(3), 395–423.

Farrell, S. (2012). The ownership and management structure of container terminal concessions. *Maritime Policy & Management*, *39*(1), 7–26.

Ganapati, S., Wong, W. F., & Ziv, O. (2021). *Entrepot: Hubs, scale, and trade costs* (Technical report). National Bureau of Economic Research.

Gomtsyan, D. (2022). Merchant networks in big cities. *Journal of Urban Economics*, *129*, 103440.

Heiland, I., Moxnes, A., Ulltveit-Moe, K. H., & Zi, Y. (2019). Trade from space: Shipping networks and the global implications of local shocks. *SSRN 3504623*.

Ma, Y., & Peverelli, P. J. (2019). Strategic decisions in Chinese state-owned enterprises as outcome of the sensemaking of the CEO: the case of COSCO's emerging involvement in the Port of Piraeus. *Transnational Corporations Review*, *11*(1), 50–64.

March, D., Metcalfe, K., Tintoré, J., & Godley, B. J. (2021). Tracking the global reduction of marine traffic during the COVID-19 pandemic. *Nature Communications*, *12*(1), 1–12.

Marczinek, M., Maurer, S., & Rauch, F. (2022). *Trade persistence and trader identity-evidence from the demise of the Hanseatic league* (Discussion paper).

Martincus, C. V., & Blyde, J. (2013). Shaky roads and trembling exports: Assessing the trade effects of domestic infrastructure using a natural experiment. *Journal of International Economics*, *90*(1), 148–161.

Martínez Moya, J., & Valero, M. F. (2017). Port choice in container market: A literature review. *Transport Reviews*, *37*(3), 300–321.

Miotto, M., & Pascali, L. (2022). *Solving the longitude puzzle: A story of clocks, ships and cities* (Working paper).

Notteboom, T. E., Parola, F., & Satta, G. (2019). The relationship between transhipment incidence and throughput volatility in North European and Mediterranean container ports. *Journal of Transport Geography*, *74*, 371–381.

Pallis, A. A., & Vaggelas, G. K. (2017). A Greek prototype of port governance. *Research in Transportation Business & Management*, *22*, 49–57.

Pascali, L. (2017). The wind of change: Maritime technology, trade, and economic development. *American Economic Review*, *107*(9), 2821–2854.

Piraeus Port Authority. (2016). *Piraeus Port Authority SA. Annual financial report for the year ended December 31, 2016*.

Psaraftis, H. N., & Pallis, A. A. (2012). Concession of the Piraeus container terminal: turbulent times and the quest for competitiveness. *Maritime Policy & Management*, *39*(1), 27–43.

Stroikos, D. (2022). 'head of the dragon' or 'Trojan horse'?: Reassessing China–Greece relations. *Journal of Contemporary China*, 1–18.

Sun, L., & Abraham, S. (2021). Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. *Journal of Econometrics*, *225*(2), 175–199.

Van der Putten, F.-P., & Meijnders, M. (2015). *China, Europe and the maritime silk road. Clingendael Institute*.

Wiltshire, J. C. (2022). *Allsynth: (stacked) synthetic control bias-correction utilities for Stata* (Working paper).

World Bank. (2003). *Port reform toolkit: Effective decision support for policymakers*. The World Bank.
Zhu, S., Zheng, S., Ge, Y.-E., Fu, X., Sampaio, B., & Jiang, C. (2019). Vertical integration and its implications to port expansion. *Maritime Policy & Management*, *46*(8), 920–938.
Zou, X. (2016). *Speech by Ambassador Zou Xiaoli at the seminar 'The New Silk Road of China: One Belt, One Road (OBOR) and Greece'*.

How to cite this article: Koenig, P., Poncet, S., Sanch-Maritan, M., Duvallet, C., & Pigné, Y. (2023). Sold to China: Container traffic in the Port of Piraeus. *Review of International Economics*, 1–35. https://doi.org/10.1111/roie.12675

APPENDIX A. EUROSTAT RANKING OF 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	4153	19	5030	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	5720	18	9327	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	7960	17	8153	18
Valletta	14,200	20	2425	20	1239	20

Source: Eurostat.