Port Competition and World Trade

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1 Introduction

With 90% of international trade being carried out by oceanic shipping, world ports emerge as powerful gatekeepers. In the proposed research, we explore the impact of ports, as strategic players, on international trade, growth, and inequality across countries. Ports have radically changed over the last 30 years. Since the 1990s, the rapid speed of globalization led to substantial investment in order to handle ever-growing ships, lower cargo handling costs, and battle port congestion. From regional, labor-intensive, low-tech harbors, the industry now features global, high-tech, capital-intensive ports that strive to gain market share of goods transported. As a result, the industry has become increasingly concentrated. Port market power might result in higher prices and longer ship waiting times, as ports may under-invest in infrastructure. The latter can result in increased inventory costs and production delays, and can substantially affect international trade.

The proposed research aims to address a number of questions related to these recent phenomena. Do ports have market power? And if so, what is the resulting impact on world trade and societal welfare? How does market power affect investment in infrastructure and thus port congestion and wait times? With two-thirds of trade loaded and unloaded in ports of developing countries, what are the implications of market power and port infrastructure on growth and inequality? We aim to build a model of port competition, and combine it with multiple novel micro-datasets (some collected by ourselves) to shed light on the role of world ports in international trade. We begin our research by comparing Europe to Africa, aiming to address the extent to which port market power, as well as port infrastructure affects differential trade patterns, growth and inequality across countries.[1]

We first describe the industry and data collected in Section 2. We then present some basic facts about ports in Section 3, and a model sketch in Section 4.

Brief Connection to the Literature The proposed research is related to the literature studying the impact of transportation infrastructure (e.g. Donaldson and Hornbeck, 2016, Donaldson, 2018, Fajgelbaum and Schaal, 2020, Allen and Arkolakis, 2021), as well as the role of geography in international trade (e.g. Krugman, 1991, Head and Mayer, 2004, Allen and Arkolakis, 2014). It also relates to an emerging literature on the impact of containerization on port development and its impact on the local economy (e.g. Ducruet, Juhasz, Nagy, and Steinwender, 2021, as well as Brooks, Gendron-Carrier, and Rua, 2021). See Friedt and Wilson (2020) for a recent survey of the impact of port investment both on local economic activity, but also on the economy more broadly. Related, Sytsma and Wilson (2020) estimate a discrete choice model of agricultural shipments in the US. We also contribute to a literature that has studied the shipping industry, e.g. Hummels and Skiba (2004), Hummels (2007), Hummels, Lugovskyy, and Skiba (2009), Ishikawa and Tarui (2018), Asturias (2020), Brancaccio, Kalouptsidi, and Papageorgiou (2020a),

[1] Anecdotally in Europe, several ports compete for landlocked countries (e.g. Rotterdam, Anthwerp, Hamburg and Le Havre compete fiercely for Germany's large industrial market). In contrast, in Africa, a small number of ports monopolize their landlocked countries (e.g. Djibouti is a de facto monopolist for Ethiopean and Eritrean trade, while Dar er Salaam is the major entry point to Tanzania as well as Zambia, Rwanda and Malawi).

Brancaccio, Kalouptsidi, Papageorgiou, and Rosaia (2020b), Wong (2020), Ganapati, Wong, and Ziv (2021) and Heiland, Moxnes, Ulltveit-Moe, and Zi (2021).

2 Industry and Data Description

Industry Description With 90% of international trade (amounting to 11 billion tons and about 20 trillion US Dollars) passing through them, world ports are a vital link of global supply chains. There is no such thing a "typical" port: there are ports at sea (deep- or shallow-water ports) and inland (on rivers, or lakes); there are tiny ports and huge ports; ports that handle different types of commodities and different types of ships and ship sizes. A port consists of a "landlord" (usually the local port authority), who owns the land; the port infrastructure (berths, (un)loading equipment, storage areas, buildings, etc.); and port services (pilotage, cargo-handling, towage, etc.) offered by either private terminal operators, or the landlord. After waves of privatizations, the infrastructure and operations of most ports are handled privately with the goal of maximizing profits. The main customers of ports are shipping companies who use port infrastructure and services; finally, the end-users are the global cargo customers (importers, exporters).

Ports compete through prices, as well as the quality of their service. The price consists of several types of charges for the usage of the port's infrastructure and services. For bulk goods, port charges can be a substantial portion of their value, roughly equal to 15% (World Bank). Additionally, ports compete through the quality of their services, largely captured by the time a ship needs to spend at port. This includes the actual (un)loading time, plus any time spent waiting outside the port at "anchorage" at times of heavy port congestion.[2] Wait times are extremely costly to ships and cargo-owners; they translate directly to monetary costs, including penalty fees ("demurrage") paid to/from shipowners and additional fuel costs. Moreover, as wait times cascade along the transportation chain (e.g. lost connections to trucks/trains) they may amount to substantial additional costs to shipowners and exporters. Hence, ports strive to offer low overall wait times both by being efficient during (un)loading and by having enough capacity to avoid congestion.

In recent years, the rapid growth of international trade has led to a striking rise in ship sizes (the average dry bulk carrier built in the last four years is 60% larger than one built twenty or more years ago). This trend challenged port capacity. Although investment in port infrastructure has increased substantially, the capital costs required to handle such ships (e.g. specialized cargo-handling equipment such as enormous cranes, land conversion, etc) are considerable, and port congestion remains an important bottleneck of international trade.[3]

Finally, we are currently focused on dry bulk shipping, which involves vessels designed to carry a homogeneous unpacked dry cargo, for individual shippers on non-scheduled routes. Bulk carriers operate like taxi cabs: a specific cargo is transported individually in a specific ship, for a trip between a single origin and a single destination.[4] Dry bulk shipping involves mostly commodities, such as iron ore, steel, coal and grain; it accounts for about half of total seaborne trade in tons (UNCTAD) and 45% of the total world fleet.

Data To address these questions we are in the process of collecting several novel, rich datasets on world ports. First, we have acquired access to detailed vessel port call data from AXS Marine for all dry bulk

[2] The anchorage is a location close to a port where ships can halt and stay protected from bad weather. Ships can also wait outside of the designated anchorages of a port. In our empirical analysis we construct port wait times by using AIS data to identify when ships are likely waiting to enter a specific port.

[3] Infrastructure improvements to accommodate current ships may easily amount to 100 million US dollars (World Bank), while a modern crane alone can cost about 6 million.

[4] It is worth noting that bulk ships are very different from containerships, which operate like buses: containerships carry cargos (mostly manufactured goods) from many different cargo owners in container boxes, along fixed itineraries/routes according to a timetable. It is technologically impossible to substitute bulk with container shipping. Tankers operate like bulkers but carry liquids, mostly crude oil and oil products.

carriers and tankers globally. Each observation involves a ship's visit to a given port and reports the date and time of arrival and departure, the time spent in the port's anchorage, and, often, the commodity (un)loaded. This dataset provides all ship movements to, from and within each port in the world. In addition, the same database provides information on ports, including port characteristics, such as the port's polygon location, the number of berths, the different terminals, and the terminal operators. The database spans 2013-2020 and includes a total of 264,525 observations, when focusing on the largest 700 ports in Europe and Africa.

Second, we merge this database to a data set of port charges, often referred to as DA's (Disbursement Accounting). This dataset, purchased from a broker firm that wishes to remain anonymous, reports a very detailed break-down of port charges for individual port calls. In other words, each observation reports a port, a ship (anonymized, though we do observe its size), the date of arrival, and several categories of port charges (e.g. pilotage, towage, berthing, cargo-handling). The data spans 2016-2020 and includes a total of 78,683 observations, when focusing on Europe and Africa.

Third, we merge these datasets with a data set on port infrastructure. With the help of several research assistants, we are in the process of manually collecting historical images of world ports from Google Earth. From the satellite images, we collect information such as the number and length of berths, storage areas (containership storage areas, silos and other facilities), nearby rail and road networks, as well as other facilities (e.g. refineries).

3 Facts

In this section, using our data, we present some basic facts about port quality provision, and how that correlates with port investment in infrastructure, as well as about competition among ports. As mentioned in Section 2, the quality of port services is largely captured by the time a ship spends at port, starting from the wait to enter the port until it finishes (un)loading. The average time at port is 163 hours, of which 100 hours are spent (un)loading and 63 waiting in anchorage to reach the berth. In Figure 1 we plot a histogram of wait times for European and African ports.[5]

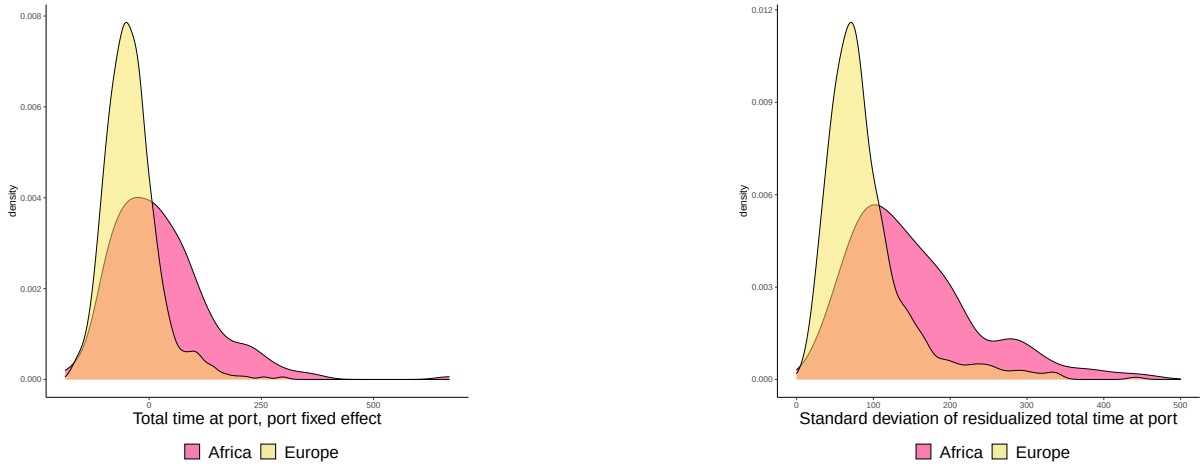


Figure 1: Port wait times. The left panel plots a histogram of port fixed effects from a regression of wait times on covariates including the commodity shipped, vessel size, (un)loading dummy, time dummies. The right panel plots the corresponding standard deviation at port level.

The average ship spends 225 hours in an African port, but only 134 hours in a European port. At an average daily shipping rate of $14,179, this correspond to a $53,171 increase in the cost of shipping a cargo

[5]To compute the wait time before entering the port, we measure the time the ship spends in anchorage within a 100km radius from the port and add the time the ship spends from entering the port and until loading/discharge operations begin.

to a port in Africa. Importantly, the difference is driven by higher anchorage times in Africa, stressing the crucial role of port infrastructure and congestion there.

In the right panel of Figure 1 we plot the standard deviation of wait times at the port level, after controlling for covariates that might affect the time at port for a ship, such as the commodity shipped, the vessel size, and time period. The histogram shows that ships face considerable uncertainty upon arriving at port, which can be quite costly, especially given the prevalence of just-in-time production. Moreover, the uncertainty is much higher in African ports.

We next explore differences in market concentration among the two continents, which may be linked, as we argue, to differences in quality provision between European and African ports. To do so, we need a notion of the markets in which ports are competing. For now, we consider each country in Europe and Africa as a separate market that needs to be reached via nearby ports.[6] Figure 2 plots the number of ports that can serve each country, as well as the corresponding Herfindahl Hirschman Index (HHI).[7] In Europe the average country is served by at least 30 ports, while in Africa, the average country has access to 7 ports, with some having access to just one (as an example, Burkina Faso). This is also reflected in the HHI: European countries' port HHI is equal to 0.24, while African countries' port HHI is equal to 0.51. It is also worth noting that considering all ports within a radius of a country is likely underestimating the degree of concentration; different countries trade in different commodities and in different quantities. Indeed, if we consider concentration within commodities or ship sizes, it rises substantially. For instance, if we focus on iron ore trade, the HHI of European (African) ports rises to 0.4 (0.7) on average. Similarly, focusing on Capesize vessels, the HHI of European (African) ports rises to 0.52 (0.64) on average.

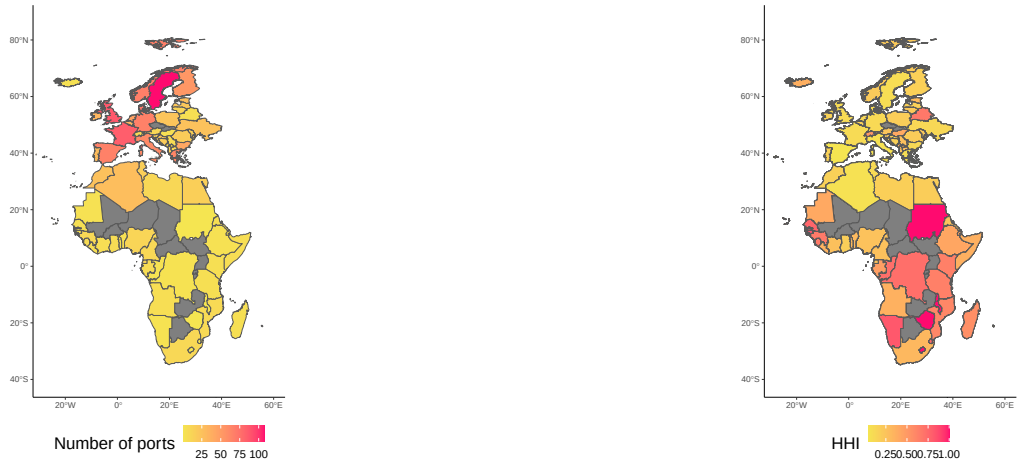


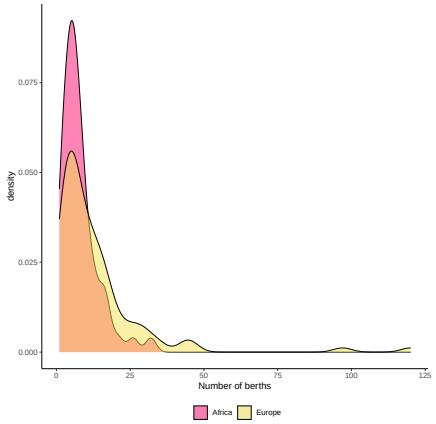
Figure 2: Port Concentration in Europe and Africa. The left panel plots the number of ports that can serve each country; the right panel plots the corresponding HHI.

In addition to differences in waiting times and in market structure, Europe and Africa also differ in their port infrastructure. Figure 3 describes different measures of port infrastructure that can proxy for port capacity. In particular, the left panel of Figure 3 demonstrates that European ports have more berths and can thus (un)load a larger number of ships at the same time, reducing wait times for ships at anchorage. Similarly, the table in the right panel of Figure 3 provides summary statistics for the infrastructure of the ten largest ports in Africa and Europe. Even though the ports in the two continents have a comparable throughput (measured in the total tonnage (un)loaded at in a month), European ports have almost 5 times more miles of berths, 5 times more silos (capturing storage for bulk goods), and substantially more acreage to store the goods loaded and discharged by the incoming ships. Hence, African ports appear

[6] We consider all ports within a 100km radius, as ports that can serve the country. This can be improved upon by considering explicitly the inland transportation network.

[7] The HHI is computed using the port call data.

more constrained.



Infrastructure for the largest 10 ports by continent		
	Africa	Europe
Average monthly throughput (dwt)	2,199,920	2,583,533
Average miles of berths	3.9	18.2
Average number of silos	375	1,860
Average area of storage space	362	624

Figure 3: Port Infrastructure in Europe and Africa. The left panel plots the number of berths in European and African ports; the table in the right panel shows how key metrics of port infrastructure compare for large European and African ports.

4 Model and Estimation Sketch

We build a simple model of port competition. Importer-exporter pairs choose which port to use in order to access their final destination. When doing so they take into account the price and expected wait time, as well as other port characteristics (e.g. road/rail network, storage facility, nearby city, etc.). The wait time is the sum of loading time and waiting (anchorage) time, which depends on port capacity and contemporaneous demand. We model port demand via discrete choice.

Ports compete in both prices and wait times. They do so by choosing their price and capacity, which in turn affects the wait times they can offer. We employ a two-stage model, where ports first choose capacities and then compete in prices.

We plan to estimate the primitives this model using the data described earlier for Africa and Europe. The main model primitives consist of price and wait time elasticities on the demand side, and port costs on the supply side. We will also estimate the wait time function (linking observed waiting times to port characteristics and demand), inspired by queuing models.

5 Conflict of Interest

None of the authors have a conflict of interest to declare.