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Article

How containerization reshaped global trade - And our cities

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César Ducruet, Réka Juhász, Dávid Krisztián Nagy and *Claudia Steinwender*

How Containerization Reshaped Global Trade – And Our Cities*

KEY MESSAGES

- **Ports boost market access to other cities and ports, driving trade and connectivity**
- **Port development imposes local costs, including land use, pollution, and noise**
- **Ports don't spur growth in their own cities, as local costs offset benefits**
- **Nearby cities gain from ports, fueling regional and national economic growth**
- **Policymakers must weigh economic and geopolitical gains against local costs**

Seaports are the backbone of global trade, handling more than 80 percent of the world's goods by volume (UNCTAD 2024). They are not just transit hubs – they are critical for countries to integrate into global production networks (Rodrigue 2016). While maritime trade has largely recovered from recent disruptions caused by geopolitical tensions and the Covid-19 pandemic, these crises have exposed the increasing fragility of global shipping. Costly rerouting, severe port congestion, and capacity bottlenecks have highlighted the pressing need for port infrastructure that is both sustainable and resilient.

However, expanding seaports around the world has become increasingly difficult (The Economist 2023). Developing a modern port requires deep water, vast amounts of land, and often comes with significant downsides, including noise, congestion, and pollution. While policymakers frequently highlight the economic benefits of ports, these advantages often extend beyond the port city itself, benefiting surrounding regions while leaving the host city to bear the costs. In a new study, we emphasize the importance of accurately measuring both the costs and benefits of port development. Understanding these trade-offs is essential for identifying the best locations for new ports and expansions – decisions that ultimately shape economic growth at both the national and global levels (Ducruet et al. 2024).

Port depth became a crucial factor in the late 1960s with the rise of containerization. Standardizing cargo into containers revolutionized shipping, cutting turnaround times by 70–95 percent (Port of San Francisco 1971; Kahveci 1999). This efficiency boost led to dramatic reductions in transshipment costs – by 70–85 percent – as ships operated more efficiently and less capital remained tied up in inventory (Rodrigue 2016). The introduction of larger vessels further amplified these cost savings, thanks to economies of scale in shipping and port handling. For instance, moving from a 2,500 TEU (twenty-foot equivalent unit) vessel to a 5,000 TEU vessel reduced per-container costs by 50 percent (Rodrigue 2016). Reflecting this trend, the average size of newly built container ships grew by an astonishing 402 percent between 1960 and 1990 (Haworth 2020). Today, ultra-large container vessels (ULCVs), stretching up to 400 meters long, can carry over 14,500 TEU of cargo.

However, there's a catch: larger ships require deeper harbors. While ports can be deepened through dredging, this is an expensive and ongoing process, as ocean currents continually deposit sediment, reducing the gained depth (Brooks et al. 2021).

To assess how a port's natural depth influences its shipping potential, we compiled a unique dataset tracking global ship movements at the port level from 1950 to 1990 – spanning the first wave of containerization. Our primary data source is the Lloyd's List Shipping Index, a detailed daily record of merchant vessels and their inter-port movements. To measure sea depth around port cities, we hand-matched this shipping activity data with high-resolution bathymetric data, which maps underwater elevation levels.

A key challenge was distinguishing naturally deep ports from those deepened through dredging – a process that can be a response to anticipated shipping growth. To avoid this bias, we measured sea depth in a "donut" area around each port, excluding the immediate harbor area where dredging is most likely to occur. To validate our approach, we compared our depth measure with nautical maps for a randomly selected sample of 100 ports that contain dredged channels. The results confirmed that our measure successfully captures natural depth rather than artificial deepening efforts.

Figure 1 illustrates how port depth became a crucial factor for shipping – but only after international container size standards were established in the late 1960s, paving the way for the rapid global adoption of containerization. Before 1970, deeper ports (at least 30 feet or 10 meters) did not experience significantly higher shipping growth compared to shallower ports.

* This is an executive, non-technical summary of Ducruet et al. (2024).

However, after 1970, the landscape changed dramatically: ports with greater natural depth saw a surge in shipping activity relative to their shallower counterparts. This shift underscores the transformative impact of containerization, as larger vessels required deeper harbors to accommodate their increasing size and capacity.

Port depth remains a critical factor in determining the success of ports, especially as ships continue to grow in size. For example, China boasts 76 port terminals capable of accommodating ships carrying more than 14,000 20-foot containers, while countries in South and Southeast Asia collectively have only 31 such terminals (Financial Times 2024).

CONTAINER PORTS REQUIRE VAST AMOUNTS OF LAND

Modern container ports also require vast amounts of land to operate efficiently. Fast turnaround times, essential for competitive port operations, can only be achieved by constructing large terminals. One of the main challenges associated with containerization is the significant amount of space needed for these terminals, making site constraints a critical factor in port development (Rodrigue 2016).

The need for vast amounts of land became evident early in the history of containerization. A 1971 report raised alarms about San Francisco's finger piers, which were inadequate for the new types of cargo handling required by containerization: "No pier facilities in the Bay Area today are capable of handling the new space requirements on this scale of new and larger container ships. (...) Thus, more berthing and backup area is needed" (Port of San Francisco 1971, 13). This shift in requirements even influenced the design of ports. While traditional breakbulk ports used narrow finger piers that allowed many ships to dock simultaneously, container ports now feature ships anchoring parallel to the shore, with ample space to spread containers for efficient loading and unloading.

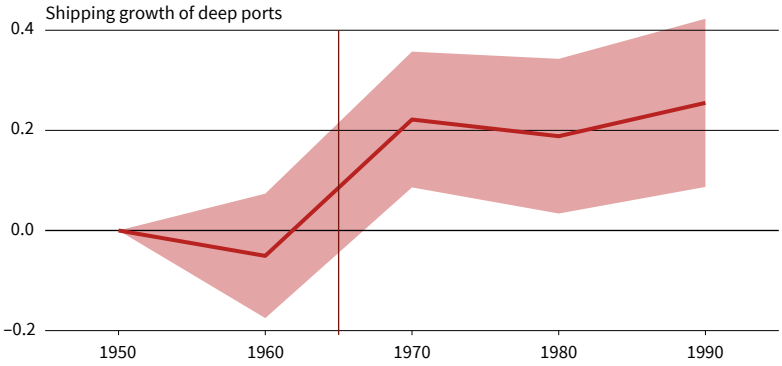
To provide systematic evidence on the relationship between containerization and land area beyond just anecdotal examples, we hand-coded the land area of ports using Google Earth and supplemented it with data on containerized shipping volumes from Le Journal de la Marine Marchande. Figure 2 illustrates that ports with a higher share of container traffic occupy significantly more land compared to those handling other types of cargo.

As soon as cargo began to be containerized, the increased land requirements led to a crisis for previously successful ports located near densely built-up cities, such as San Francisco and New York (Port of San Francisco 1971; Corbett 2010). In contrast, newer port cities that did not face these constraints, such as Seattle and Oakland, were able to develop successfully (Property Book 1961 and 1973). By analyzing detailed engineering maps and cargo throughput data for the Port of Seattle, we found that the port's area expanded fourfold, while its land intensity (i. e., the area of the port relative to throughput) nearly doubled between 1961 and 1973 – the period when the port transitioned to containerization.

Figure 3 demonstrates that this pattern holds more generally. We measure the scarcity of land in port cities using the methodology outlined in Saiz (2010), which involves counting all sea cells, internal water bodies, wetland areas, and cells with a gradient above 15 percent. These cells, as a proportion of the

Figure 1

Deep Ports Grew After Containerization



Source: Authors' calculations. © ifo Institute

Figure 2

Container Ports Occupy Large Areas of Land

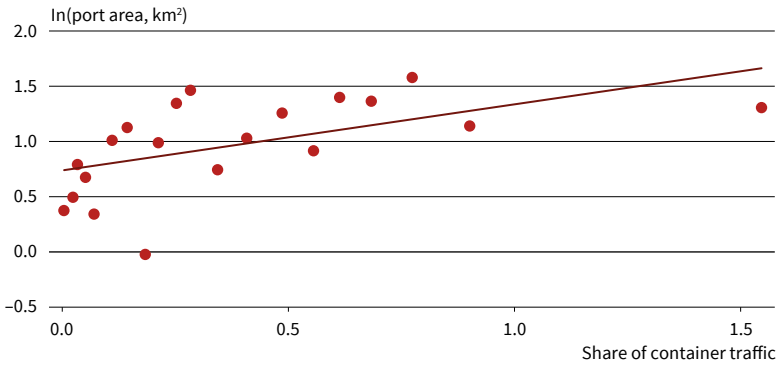


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Figure 3

Only Land Abundant Port Cities Saw Their Shipping Flows Increase After Containerization

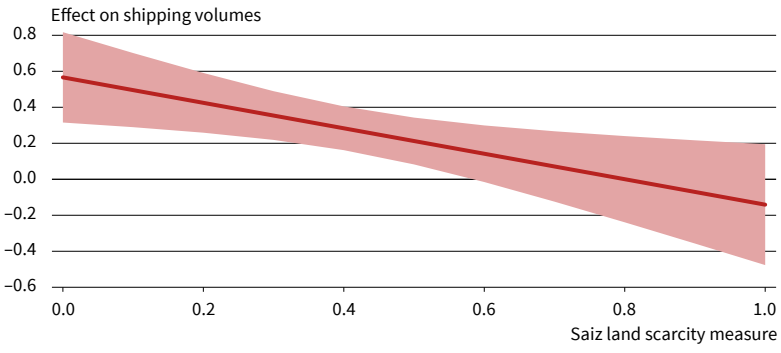

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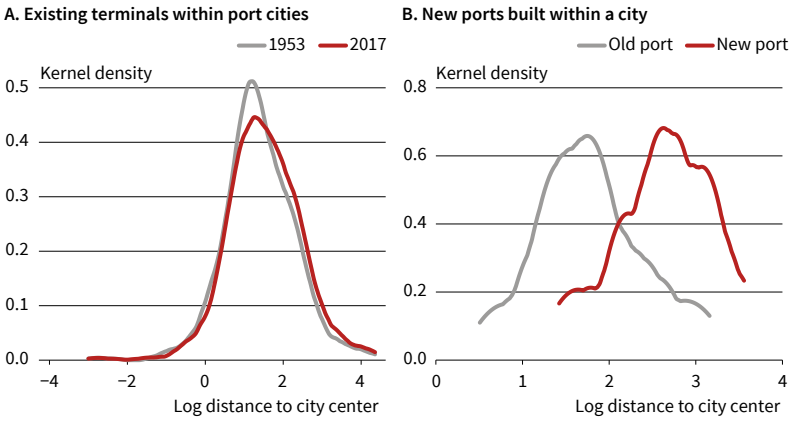
Figure 4

Within Cities, Port Terminals Moved Away from the City Center



Source: Authors' calculations.

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total area, serve as a proxy for a city's land scarcity, as they are unsuitable for development.[1]

As shown in Figure 3, cities with limited land (i. e., those to the right of the graph) did not experience significant shipping growth. Therefore, the post-containerization shipping boom was primarily driven by cities with abundant land (i. e., those to the left of the graph).

A second test of whether the increased land requirements of port development influenced the location of ports comes from examining how the location of ports changed within cities over time. Figure 4 illustrates that, over the period from 1953 to 2017, ports systematically shifted to the outskirts of cities, where land is generally less scarce. The left graph in Figure 4 focuses on existing terminals within port cities and shows that the distribution of port terminals in 2017 (red line) is shifted to the right of the distribution in 1953 (blue line), indicating that existing ports expanded outward from the city center (by about one kilometer on average). The right graph in Figure 4, which focuses on new ports built within a city, reveals an even starker shift: on average, new ports were located about nine kilometers further from the city center than those established in 1953.

[1] Some port cities attempt to address land scarcity by reclaiming land from the sea, typically by filling water bodies with materials such as sand, rocks, or soil. For example, Singapore invested USD 2 billion between 2004 and 2015 in extensive land reclamation (Chng 2016). However, when we systematically analyzed data on land reclamation in ports worldwide, we found no evidence that it was widespread enough to offset the importance of natural land scarcity, likely because land reclamation is a highly costly process.

PORTS CREATE POLLUTION

Ports also generate significant local disamenities, including noise, water, soil, and air pollution. In Hong Kong, for example, more than half of the sulfur dioxide emissions are linked to shipping (OECD 2014). Marquez and Vallianatos (2012) estimate the economic cost of pollution from the ports of Los Angeles and Long Beach to be USD 30 billion annually, which includes costs related to deaths, medical care for illnesses, and lost productivity from missed school and work days. This is equivalent to 5 percent of Los Angeles's GDP. These environmental concerns have even led to a halt in port expansions in places like Piraeus, Greece, and Veracruz, Mexico (The Economist 2023).

PORTS DO NOT CREATE ECONOMIC BENEFITS FOR THEIR OWN CITIES

Despite the significant costs associated with port development – stemming from land use, pollution, and other local disamenities – policymakers in both wealthy and developing countries continue to invest heavily in port infrastructure, suggesting that they believe port development brings substantial economic benefits. A recent example is China's Maritime Silk Road project, part of the Belt and Road Initiative, which involves the expansion of 24 port cities across Asia, Africa, and Europe (OECD 2018).

To estimate the long-term effects of containerization-induced port development on the economic growth of cities, we compare the population growth of deep and shallow port cities after containerization became widely available in the late 1960s. We use city population data worldwide for locations with more than 100,000 inhabitants, drawn from Villes Géopolis (Moriconi-Ebrard 1994), covering each decade between 1950 and 1990. The advantage of this data, compared to other sources, is that it specifically tracks populations within urban agglomerations – i. e., the number of inhabitants living in a city's contiguous built-up area – rather than administrative boundaries, which are often used in country-specific sources. This definition ensures that ports are included within the city's population count, even if they lie outside the official administrative boundaries. We hand-matched ports from the shipping data to cities based on whether the port was located within the urban agglomeration of a city in the Geopolis dataset, allowing for multiple ports to be linked to a single city.

We would expect port cities that successfully adopted containerization to experience growth as they reap the benefits of port infrastructure. Surprisingly, however, this is not con-

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firmed by the data. Figure 5 shows that, in our baseline estimates, which include all port cities worldwide in our dataset, we estimate a small, positive, but statistically insignificant effect of shipping activity on population growth. Importantly, this result is not driven by specific countries or continents, as the effect remains statistically indistinguishable from zero even when we exclude certain continents from the analysis.

Our estimates reveal that, contrary to what many policymakers might expect, successful container port cities do not experience population inflows. However, considering the significant costs associated with port development mentioned earlier, this result becomes less surprising. To better understand the dynamics at play, we employ a quantitative general equilibrium model of cities worldwide to separate the costs and benefits of port infrastructure investments. To estimate city-level GDP per capita for all cities worldwide, which is not available from existing sources, we combine existing estimates of city GDP for a subsample of cities (from the Canback Global Income Distribution Database) with satellite data on nightlight luminosity. This allows us to extrapolate GDP per capita for the full sample of cities, building on a growing body of evidence suggesting that income can be reasonably approximated using nightlight luminosity data (Donaldson and Storeygard 2016).

The model incorporates port development into an otherwise standard economic geography model of trading cities. Port development is costly for two main reasons: it requires scarce local land and generates disamenities in the port city, such as pollution and noise. As a result, the model not only considers the typical benefits of port development – such as improved market access through maritime trade – but also takes into account the local costs associated with port development, including land use and disamenities. Whether a city ultimately experiences population growth depends on the trade-off between the market access benefits and the local costs of port development.

Using the model, we pinpoint that the lack of growth in port cities is specifically driven by the significant costs of port development. While ports enhance a city's attractiveness by improving integration into the global transport network, these benefits are counterbalanced by two key factors: the scarcity of land, which limits expansion, and the environmental costs associated with port activities, such as pollution. As a result, there is no effect on the growth of port cities.

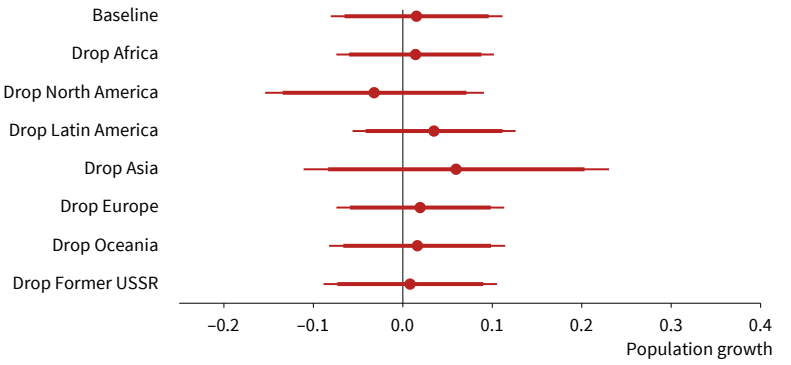
PORT CITIES BENEFIT CONNECTED SURROUNDING CITIES

Does this mean that the widespread investment in port development around the world is futile? The answer is no. While port cities themselves may not experience significant growth, surrounding cities do benefit: they gain improved access to global markets without bearing the direct costs of port development. This highlights the importance of port location in shaping economic growth and welfare in nearby cities. The development of specific ports influences global shipping patterns and plays a crucial role in determining how economic growth is distributed across cities and countries worldwide.

We illustrate this dynamic by analyzing China's Maritime Silk Road project. As part of the Belt and Road Initiative, the Chinese government is subsidizing and investing in numerous ports across Africa, Asia, and Europe (Koenig et al. 2023). Our analysis estimates that this initiative will significantly reshape shipping patterns in Asia. Most strikingly, Singapore is expected to lose shipping traffic to nearby Asian ports. However, despite this decline in shipping activity, Singapore is projected to experience economic gains. By reallocating its scarce land toward more productive sectors, such as services, Singapore's GDP would actually increase rather than decline.

Figure 5

Effects of Depth on Shipping on Population Growth Across Cities



Source: Authors' calculations.

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POLICY CONCLUSION

Our analysis highlights key factors that policymakers worldwide must consider when planning port development. First, our findings raise the question of

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whether today's ports are optimally located. Given the land-intensive nature of port infrastructure, we must ask whether some of the world's most expensive cities – such as Hong Kong and Singapore – should continue to specialize so heavily in port activities. While these cities historically reaped enormous benefits from their roles as major shipping hubs, productivity growth in other sectors has made the opportunity cost of allocating land to port expansion increasingly high.

This suggests that Hong Kong and Singapore might benefit from following the path of London and New York. Once dominant centers of global shipping, these cities have redirected their resources toward higher-value industries, such as financial services. A similar shift is already underway in parts of Asia, where "global hub-port cities" (Lee et al. 2008) are emerging. These cities develop port infrastructure on the urban periphery while dedicating downtown areas to advanced services. Recent examples include Yangshan Island (Shanghai), Jurong Island (Singapore), New Priok (Jakarta), and Nhava Sheva (Mumbai).

Of course, economic considerations are not the only factors influencing port development decisions. Governments may also prioritize geopolitical advantages, such as maintaining a strategic position in global shipping networks. However, our analysis underscores the importance of clearly distinguishing between economic and geopolitical objectives when planning port infrastructure. Transparent decision-making that accounts for these trade-offs can help ensure that port investments align with broader national and regional development goals.

Second, in many developing countries, land market frictions may be a major barrier to port development (Sood 2022), limiting the ability to expand or modernize port infrastructure. As the global economy adjusts to shifting geopolitical dynamics and a heightened focus on supply chain resilience, policymakers must carefully consider port development. This means weighing not only the economic and geopolitical benefits but also the significant local costs – particularly land constraints and environmental impact – to ensure that investments in port infrastructure are both sustainable and strategically sound.

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