Getting Workers 'On Board' with Automation: Evidence from Shipping Container Adoption and Longshore Unions*

Jacob Greenspon[1]

[1]University of Oxford

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Abstract

Workers at a firm that is considering adopting a labour-saving technology face a dilemma. Preventing adoption at their own firm protects against their direct displacement. However, if they are unable to block the technology industry-wide, then product demand—and jobs—may shift toward competitors that enjoy productivity gains from adopting the automation. I explore these dynamics in the mid-20th century 'containerization' of US oceangoing shipping. This innovation drastically reduced the labour intensity of cargo handling services, resulting in substantial cost-savings that attracted customers to ports that adopted it. I first show in a TWFE approach that dockworker employment fell in ports that containerized (a direct displacement channel) and decreased by a similar magnitude following the containerization of competing ports (indirect displacement). Using newly-digitized product-by-port cargo throughput data I also show that demand for cargo handling services increased after a port containerized. I next use a geographic cost shifter IV to show that early-adopter ports increased their share of the US cargo-handling market and of total dockworker employment. Finally, I test historical arguments that divergent approaches by two dockworker unions to the threat of containerization influenced adoption timing across ports. Using newly-digitized data on union locals membership, I find that the probability of early container adoption decreases in union density among East Coast ports where the union obstructed containerization, but increases in density among Pacific ports where unions cooperated in exchange for compensatory payments, controlling for other potential predictors of early adoption. This suggests that in the latter higher unionization rates facilitated bargaining for rent-sharing from automation.

*Doctoral candidate, Department of Economics, University of Oxford; currently visiting at the Harvard Kennedy School of Government. Email: jacob.greenspon@economics.ox.ac.uk. I thank Noam Yuchtman, Nathaniel Lane, Daniel Gross, Robert Margo, Douglas Gollin, Niclas Moneke, Hillary Vipond and participants at several workshops and conferences for valuable feedback on earlier drafts. I also thank the University of Oxford Centre for Research on Structural Transformation and Growth and Rothermere American Institute as well as the Social Sciences and Humanities Research Council of Canada for funding, staff at the Harvard Center for Geographic Analysis and University of Oxford Bodleian Map Room for research support, and Nana Ama Kwayowah Ofosu for research assistance.

1 Introduction

Accelerated development of artificial intelligence, robotics, and other automation technologies offers the prospect of reversing long-term slowdowns in labour productivity growth. However, labour-saving technologies are often controversial. The adoption of automations may be hindered, or even blocked entirely, by workers threatened by displacement (Mokyr, 1992; Caprettini and Voth, 2020; Rauh and Golin, 2023; Frey, 2019), especially if they have strong bargaining power.[1] This can result in foregone productivity and overall welfare gains. In October 2024, for example, longshoremen at U.S. Atlantic and Gulf coast ports went on strike over the prospect of new automation technologies that both employers and industry analysts agreed were sorely needed to improve efficiency.[2]

Workers are typically unable to prevent all firms in an industry from adopting the labour-saving technology. In tradeable and competitive industries the firms that do adopt, and successfully translate their productivity gains into lower consumer prices, may be able to steal business from firms that are unable to adopt the automation. These non-adopting firms could therefore face declining demand for their products—with potential negative implications for their workers. As a result, workers face a dilemma when an automation technology is developed for their industry: blocking adoption at their own firm prevents their immediate replacement by the technology, but early-adopter firms may increase production at the cost of business—and jobs—at non- or late-adopting rivals. How then should workers respond to this automation threat? How should employers consider these dynamics when deciding whether to adopt new technologies?

Empirically analyzing these dynamics requires detailed data on an industry with observable technological adoption, firm and worker long-run outcomes, inter-firm competition, and worker bargaining power and strategic approaches. In this paper I study 'containerization': the adoption of shipping containers for oceangoing cargo stowage in the mid-twentieth century United States. Beginning in 1956, and drastically expanding internationally from 1966, shipping lines began packing goods in containers, rather than as separate 'breakbulk cargo' items packed tightly throughout ships' holds, and ports invested in dockside cranes to hoist these boxes on and off ships. This meant a few workers with a large crane could move as much freight on and off cargo ships in a few hours

[1] In an early example, Queen Elizabeth I blocked invention of a stocking frame in 1589 after lobbying from English hosiers whose livelihoods depended on knitting stockings by hand (Schneider and Vipond, 2023). More recently, Hollywood screenwriters bargained for limitations against the use of generative artificial intelligence following a 2023 strike (Coyle, 2023).

[2] See e.g. https://www.nytimes.com/2025/01/08/business/economy/ports-longshoremen-contract-talks.html

as several crews of a dozen longshoremen and stevedores could in days.[3] Shipping productivity improvements from containerization increased overall welfare, and developing container handling facilities in ports could be very profitable for port owners. However, they severely threatened dockside cargo handling jobs.[4] Both contemporary commentators (Weir, 1967) and some later analyses (El-Sahli and Upward, 2017; Gomtsyan, 2016) document the mass dislocation of dockworkers following containerized shipping adoption. Some responded with an adversarial approach to containers, with one union leader pledging he would "not see the dockworker made a human sacrifice to 'progress'" (ILA, 1959). Other union leaders, however, recognized the threat of containerization would not disappear, and negotiated for their members to accept buyouts and other job transition assistance in exchange for not opposing containerization at their docks (Schwarz-Miller and Talley, 2002). Elsewhere, in ports with weak dockworker unions, containerization proceeded without resistance.

The containerization of some ports meant that the services provided by dockworkers everywhere—inter-modal cargo transshipment— re-concentrated in fewer ports, typically those early-to-adopt containers (e.g. Newark, NJ or Oakland, CA), which served increasingly-larger container ships (Hall, 2009). Ports that had previously been among the largest in the US, but never incorporated containers into their cargo transshipment processes (eg. Brooklyn or Manhattan, NY) or adopted too late to catch up to earlier adopters (eg. San Francisco, CA), declined significantly thereafter (Levinson, 2006). Indeed, most of the largest US container ports today were among the earliest ports to containerize.[5] Dockworkers whose union successfully preventing container adoption in their port protected against their *direct* displacement by machines. But it may have reduced demand for cargo handling services at their port—and thus *indirectly* hurt their employment—as boats shifted to visit only more productive containerized ports, and goods then traveled by land to (or from) their final destinations (or initial sources).

I measure the competitive threat that any given port faces from containerized ports based on their proximity. For a goods importer, the alternative to having their products unloaded at the

[3]For example, the first purpose-built container crane, installed in Houston, TX in 1959, loaded a 40,000-pound box every three minutes, translating to 400 tons per hour, which was over 40 times the average productivity of a longshore gang using shipboard winches (Gomtsyan, 2016).

[4]While at times 'longshoreman', 'stevedore', and 'dockworker' had slightly different meanings, in this paper I use the terms interchangeably in accordance, for example, with titles in occupational classifications.

[5]Six of the ten current largest US container ports (in 2021 in terms of TEU (twenty-foot equivalent unit) tonnage) were among the first seven ports to containerize: Angeles, CA; Long Beach, CA (containerized 1960 and combined in my data); Port of New York and New Jersey (Newark, NJ adopted 1956); Savannah, GA (1971); Port of Virginia (Norfolk adopted 1968); Houston, TX (1956); Charleston, SC (1970); Oakland, CA (1959); Tacoma, WA (1970); and Seattle, WA (1964). Of the 22 largest US ports today in my data (excluding Puerto Rico, Hawaii, and Alaska), all but one containerized by 1972.

port in their own city is shipping them through a competing port further away and transporting the goods over land to their final destination (with the same logic in reverse for goods exporters). The substitutibility between ports is therefore based on the cost of land transportation. I capture this via a market access style measure of the degree of 'containerized competition' faced by each seaport in each year from all other ports that have containerized by that time, using estimates of contemporaneous county-to-county land transport costs (Jaworski and Kitchens, 2019) and data on container adoption timing from Brooks et al. (2021). This improves on previous work that studies these indirect impacts of automation on employment with relatively coarse measures of adoption within a manufacturing industry code (Koch et al., 2021; Acemoglu et al., 2020).

My empirical analysis begins by first regressing annual dockworker employment at a port on the full interaction of an indicator for whether the port had containerized by that year and the degree of containerized competition it faced from elsewhere, in a two-way fixed effects model. I find that dockworker employment decreases following own-port containerization and decreases by as large a magnitude with a one standard deviation increase in containerized competition. These competitive threats are neutralized after a port containerizes. To explore firm-side outcomes I run similar regressions where the dependent variable is the annual volume of container-suitable cargo handled by a port, using newly-digitized data on annual port-by-product cargo throughput from historical US Army Corps of Engineers reports (USACE, 1953). I find that the demand for cargo transshipment services at a port increases with its own containerization, especially when controlling for the level of competition it faces, suggesting that containerization also benefited port owners.

I next show that containerization entailed a first-mover advantage as early adopting ports increased their share of the total cargo transhipment market and workers in these ports enjoyed more employment opportunities. I instrument for early containerization using a port's channel depth before container technology became available, following Brooks et al. (2021) and Ducruet et al. (2024). Since container ships are larger than traditional break-bulk ships, naturally deeper ports can accommodate them without costly dredging and are therefore more likely to adopt containers earlier. Specifically, I regress each port's share of total US container-suitable cargo handling (in terms of both tonnage and estimated value) in 1970, 1977, and 1985 on an indicator for whether the port was an early adopter of containers (by 1970) instrumented by its 1953 channel depth. Controlling for several potential confounders, I find that, compared to ports that had not containerized by 1970, early-adopter ports had significantly higher demand for their services in

1970 and later years. I find similar results for regressions where the outcome is a port's share of total US dockworker employment in each year from 1970 to 1996. Early adoption appears to benefit both workers and firms (port owners).

Finally, having established that containerization resulted in dockworker dislocation via both direct displacement and indirect substitution away from non-adopting ports, and that early adopter ports and their workers enjoyed a first-mover advantage, I explore how workers responded to this technology and whether this shaped its adoption. The two major US dockworker unions took different approaches to the threat of containers. On the East Coast, the International Longshoremens Association (ILA) obstructed adoption wherever possible, while the International Longshore and Warehouse Union (ILWU) bargained to support containerization in its Pacific Coast ports in exchange for employers "buy[ing] out the property rights of registered workers" (Goldberg, 1968). I explain these divergent based on historical accounts and a simple game theory model of competing unions deciding how to approach the threat of automation technological adoption to illustrate which influence their stances. I show that a union's beliefs around the degree of product demand that will shift to adopting firms and the size of compensation they will receive both shape whether the union supports adoption. This is in line with historical accounts where the ILWU, but not the ILA, recognized the indirect threats to longshore jobs from ports *not* containerizing and also was able to effectively bargain with employers to compensate displaced longshoremen due to its high degree of centralization and healthy negotiating history.

I argue that in ports with higher dockworker union density, workers had more credibility when either bargaining with port owners over compensation in exchange for cooperating with containerization, or when threatening to oppose adoption. I find that early adoption is positively associated with union density in cooperative-bargain ports but negatively associated with density in ports that opposed containerization, using new estimates of pre-container dockworker union density by port from digitizing union locals membership records (ILA, 1955; ILWU, 1955). In an empirical analysis I look at predictors of early container adoption in a port. I leverage variation in local union density that shapes the ability of unionized workers in a given port to either uphold a union-wide bargain, or to credibly oppose adoption. I control for other possible predictors of adoption from the literature, including ex-ante output and competition as well as the port-depth instrument and a similar dockside land supply cost shifter. I include these potential confounders in a regression of early containerization on dockworker union density (a measure of local bargaining power) with

separate coefficient estimates for each of the two coast-wide dockworker unions. I find that the probability of early container adoption decreases in union density among Atlantic and Gulf coast ports (whose union fought containerization to protect all dockworker jobs) but increases in union density among Pacific ports (whose union bargained to cooperate in exchange for job buyouts for union members only). This suggests that in the latter, higher unionization rates facilitated bargaining for rent-sharing from automation, contrary to most previous research where greater worker representation hinders adoption. Understanding the role of these factors generally, and lessons from container adoption specifically, can shed light on how to encourage automation today in industries with substantial worker bargaining power.

Contribution to literature. This paper builds on several strands of research related to shipping containerization, worker displacement from automation, and the influence of unions on technological change in a firm.

I use newly-digitized historical data on cargo throughput and dockworker employment by port to study the impacts of containerization on cargo transshipment firms and longshoremen. Previous research has mainly focused on the drastic reductions in trade costs, and increases in trade flows and economic development, that containerization enabled (Levinson, 2006; Coşar and Demir, 2018; Hummels, 2007; Bernhofen et al., 2016, 2021). Bridgman (2024) argues that the reduction in shipping costs at US ports from containerization was delayed by a decade after its 1965 adoption into international shipping. He attributes this delayed impact to compensation deals for longshoremen that artificially inflated labour costs despite increasing labour productivity in containerized ports. While I do not study these shipping or labor costs specifically, in contrast I find a much earlier impact (by 1970) of containerization increasing demand for cargo transshipment in early-adopting ports and earnings for dockworkers in those ports. More recent studies have also estimated increases in local population around containerized ports due to increased market access (Brooks et al., 2021; Ducruet et al., 2024), highlighting the positive impact of container adoption on local economic development.[6]

The impact of containerization on dockworkers received much attention from contemporary commentators (Glazier, 1960; Weir, 1967; Fairley, 1961; Ross, 1968, 1970; Goldberg, 1968) and later scholars (Donovan, 1999; Herod, 1998). However, in contrast to research on trade costs and population growth, there has been less empirical research on containerization's labour impacts, especially

[6]Brancaccio et al. (2024); Blonigen and Wilson (2008) and Clark et al. (2004) also show the importance of port productivity in general for increasing trade.

in the US where it was first adopted. El-Sahli and Upward (2017) document the employment and earnings trajectories of British dockworkers using 40 years of longitudinal micro data. They find that union-negotiated job guarantees protected dockworker employment until the guarantees were removed three decades later and that even after their expiration dockworkers did not experience worse labour market outcomes than observably similar workers. Work in the U.S. has been limited by insufficiently detailed historical data on dockworker employment. Gomtsyan (2016) looks at the share of workers employed as longshoreman in both containerized and non-containerized ports, finding that after the onset of containerization this share declined across all ports, with steeper declines in initially larger ports (but also larger declines in overall unemployment in these ports). He does not analyze the number of dockworkers employed in each port nor their earnings and also does not take into account differential container adoption by ports, indirect effects of containerized competition on workers (especially competing ports within the same metropolitan area labor market, such as New York City and Newark), or how worker unions navigated job threats from containerization. Hall (2009) also analyzes earnings of US dockworkers but only after 1975 and with a focus on the effects of deregulation. He finds that dockworkers in the 11 largest US container port cities (as of 2005) had a statistically significant earnings premium compared to dockworkers elsewhere in the US, which grew from the late 1970s until 2005. I build on this prior research by using data on dockworker employment counts by US county starting before containerization began in 1956 (from Eckert et al. (2022)) to study labour market impacts in adopting and non-adopting ports. I also add a new analysis of firm outcomes, from newly-digitized data on cargo throughput by port, as well as examine the influence of dockworker unions on adoption with newly-digitized data on union locals membership.

In studying impacts of containerization on dockworkers, this paper builds on a growing body of research on worker displacement and job trajectories after automation, both historically (see review in Schneider and Vipond (2023)) and more recently (Humlum, 2020; Bessen et al., 2019). Historical episodes of technological unemployment are often found to have substantial and lasting impacts. For example, Cockriel (2024) finds that American shoemakers most exposed to adoption of a boot-stitching machine in the 1860s lost over 2 years worth of earnings, with almost as large declines for their children. While this paper does not study intergenerational outcomes, I do find lasting declines in dockworker employment following containerization. Other work finds that mechanization in the late 19th century led to both job loss and creation of new roles (Atack

et al., 2019), which echoes my findings of increases in the share of cargo handling workers in jobs that benefited from containerization, such as crane operation and mechanics. Most research on the labour market impacts of automations also focuses on local service sectors (e.g. Feigenbaum and Gross (2020)) or on manufactured goods (e.g. Boustan et al. (2022); Koch et al. (2021)). Given the competition among ports for attracting transshipment business, the containerization of cargo handling dockwork can be considered automation of a tradeable services sector, a context in which these dynamics have rarely been studied. Containerization may therefore have stronger parallels to modern tradable service industries where unionized workers may be threatened by–and influence the pace of—automation, such as warehousing or retail sales. The tradability of the cargo transshipment sector also allows me to study indirect job displacement from automation, via business stealing by containerized ports from non-adopters. Most of the empirical literature on jobs and automation studies only how workers are impacted by their own employers adopting technologies. The exception is analyses by Acemoglu et al. (2020) and Koch et al. (2021) of how workers across all firms within a French and Spanish (respectively) manufacturing industry are impacted by robot adoption by certain firms within the industry. My contribution here is a more robust measure of the degree of automation competition faced by firms over time, from spatial competition among ports, which I use to explicitly estimate both direct and indirect disemployment impacts of automation. I find the latter is nearly as large in magnitude as direct displacement, which suggests that workers may be misguided in seeking to block automation at their own firm (Rauh and Golin, 2023) if they nonetheless face reduced labor demand due to business stealing by competitors that do adopt productivity-improving technologies. It is therefore important for workers to consider both sources of dislocation when deciding their stance on automation threats, as some dockworkers appeared to (Herod, 1998).

In examining how workers respond strategically to threats of technological unemployment, I contribute to previous work on "technological resistance" (Schneider and Vipond, 2023) as well as a wider literature on directed technical change (Acemoglu, 2002). Historical research on the former has focused on "machine breaking" in the first industrial revolution (Nuvolari, 2002; Caprettini and Voth, 2020), where workers without union representation attempted to delay adoption of automations that would reduce demand for their labour. Other research has focused on guilds of skilled artisans, arguing they opposed technologies that undermined their position in markets (Mokyr, 1992; Rosenberg and Curci, 2023; Epstein, 1998). Research focused on more recent periods

typically views their modern analogues—labour unions—as negatively impacting incentives for firms to invest in new technologies because of the risk of a union's ex-post hold-up power (Grout, 1984; Card et al., 2014; Cardullo et al., 2015).[7] Labour conflicts that hinder technological adoption may meaningfully contribute to regional economic decline (Alder et al., 2023).

However, union bargaining power may not necessarily hinder technological adoption (Berton et al., 2021; Dowrick and Spencer, 1994). Insider-outsider theories of labor unions argue that they protect incumbent workers (Lindbeck and Snower, 2001) and therefore resist automations that displace them. Compensating workers that are displaced may mitigate this opposition. On the US Pacific Coast, where union members received high levels of compensation, the probability of early adoption was increasing in union bargaining power. Theoretical work by Tauman and Weiss (1987) also finds that unions may increase adoption of technologies that attract new demand or help surmount competitive threats. This fits with dockworkers recognizing the competitive threat to their jobs from their port losing business if it did not containerize. A similar view argues that in oligopolistic markets, unions that have bargained for higher employment levels incentivize firms to innovate in order to protect their market shares (Beath et al., 1989; Ulph and Ulph, 1994).[8] This may only hold if unions can credibly commit to facilitating the adoption of an innovation that boosts productivity, which may be more difficult with labour-saving technologies. I find that local union density predicts containerization in ports organized by the more centralized Pacific-coast dockworker union and not in ports organized by the relatively decentralized east coast union, in line with the latter being less able to credibly commit to allowing containerization. This also aligns with Haucap and Wey (2004) who argue that firms' investment incentives are largest under centralized unions. Together, these results fit with more positive views of unions' influence on technological adoption and worker outcomes. Acemoglu and Johnson (2024) argue that shared prosperity from technological change after 1850, where both wages and profits increased, was "undergirded by a changing balance between capital and labor, as...trade unions were empowered to negotiate wages and working conditions."

Finally, this paper relates to a limited empirical literature on the role of competitive dynamics in firms' technological adoption decisions. Schmidt-Dengler (2024) finds that US hospitals'

[7] A complementary literature also studies the impact of unions on *innovation*, rather than technological adoption (Bradley et al., 2017; Menezes-Filho et al., 1998).

[8] However, this literature focuses primarily on research and development (e.g. Menezes-Filho et al. (1998)), rather than technology adoption. Another view is that unions boost labour productivity by acting as collective voice institutions that increase effort, improve knowledge-sharing and innovation within a firm, and reduce turnover (Freeman and Medoff, 1984).

adoption of MRI machines is motivated to a small, but significant, extent by their desire to pre-empt adoption by rivals rather than solely considering their own marginal benefits. This builds on a larger theoretical literature on competitive dynamics in adoption (Ruiz-Aliseda and Zemsky, 2006), and specifically the role of preemption on the timing of adoption (Fudenberg and Tirole, 1985; Riordan, 1992). To the best of my knowledge, this paper is the first study of competitive dynamics in adoption of automation technologies specifically, for which it is more important to incorporate dynamics around workers facilitating or opposing the adoption.

2 Historical background

Until the mid-twentieth century, oceangoing shipping of general cargo was all 'break-bulk': items were packed individually into ships holds, either loose or in small containers such as boxes, barrels or pallets (El-Sahli and Upward, 2017).[9] The dockside services that moved this cargo between ships and land-based transportation such as railcars and trucks—hereafter defined as ocean transshipment shipping—were primarily manual: longshoremen used some tools such as hooks, pulleys, or winches but often relied on their brute strength to move cargo. This is illustrated in the images in Figure 1 of both breakbulk goods and containers .

Figure 1: Transmodal cargo shipping before and after containerization



(a) Break bulk: US ship in Korea, early 1950s



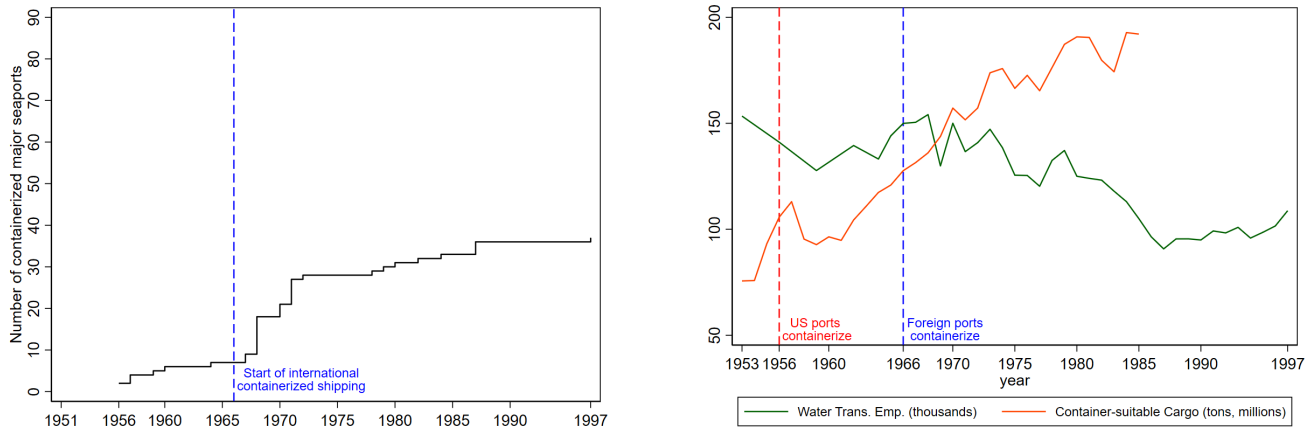
(b) Containerized: Sea-Land *Ideal-X*, late 1950s

Notes: Source: Wikimedia Commons and Port Authority of New York and New Jersey

[9]Note the focus here is on 'general cargo' goods that were the most labour-intensive to move on/off ships and small enough to fit in containers (eventually standardized at 40 feet long) rather than tankers (eg. oil) or dry-bulk shipments (e.g. wheat).

The containerization era began in 1956 when the *Ideal-X* sailed from Port Newark to the Port of Houston (Gomtsyan, 2016). It drastically expanded with the introduction of containers into international shipping in 1966. Figure 2a shows the number of containerized US seaports over time. While the idea of packing goods into boxes had been experimented with since the late nineteenth century, it was not successfully adopted until integration with other cargo transport innovations (Levinson, 2006). This involved substantial capital investments by port owners—typically cities or quasi-public port authorities—into dockside container-handling facilities featuring cranes, and by shipping firms into containers and container-specialized boats. By reducing the time required for all three parts of the breakbulk cargo (un)loading process—bringing goods from warehouses to winches; lifting cargo into (or out of) ships' holds; and packing cargo in efficiently (National Academy of Sciences, 1957)—containerized shipping drastically reduced the time ships spent in port and the labour requirements of on- and off-loading cargo, two of the most important costs to trade at the time (Levinson, 2006). Ships spent 90 to 94% less time moored in containerized ports, which allowed for larger vessels that caused greater efficiencies via returns to scale (Ducruet et al., 2024). These translated to a large decrease in shipping costs, on the order of a 16 to 22% decrease in variable shipping costs (Coşar and Demir, 2018). These efficiencies convinced many ports that the capital investments associated with adoption were worthwhile.

Figure 2: Containerization timing and dockworker employment and cargo handling trends

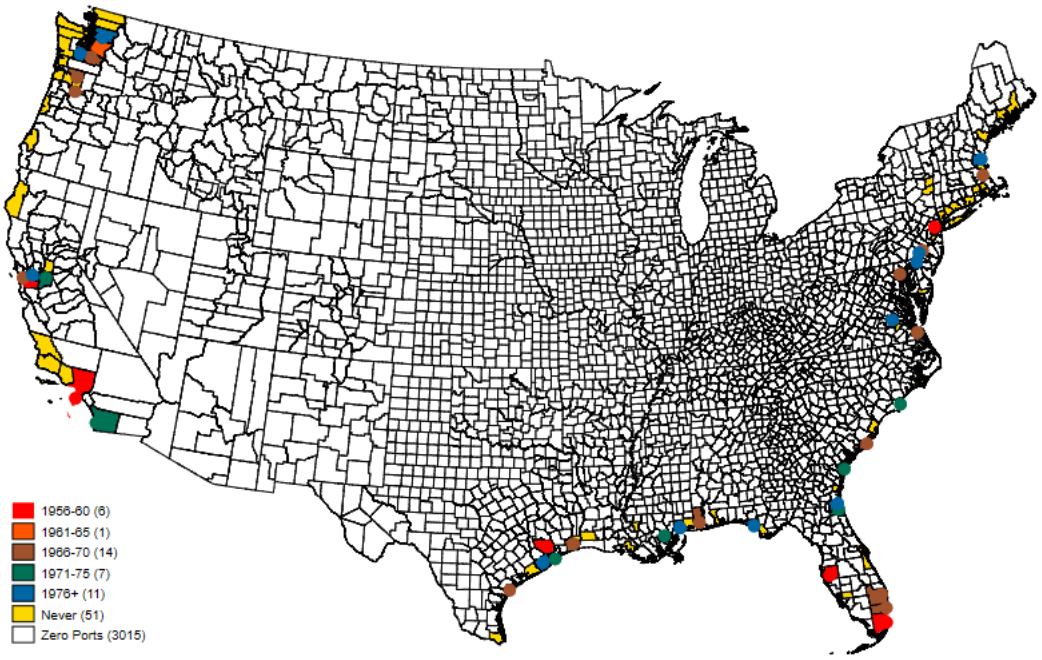


(a) Number of containerized seaports in sample

(b) Total employment and cargo volume

Notes: Panel (a) shows the total number of major seaports that had containerized by each year, out of 90 total in sample, with port containerization timing from Brooks et al. (2021). Panel (b) shows total employment across these seaports in the overall Water Transportation sector, with County Business Patterns (CBP) data from Eckert et al. (2022) beginning in 1951, and the estimated total tons of container-suitable cargo handled by these seaports, with shipping data from USACE (1953) from 1953 to 1985 and product container-suitability as assessed in 1968 and reported by El-Sahli (2013).

Figure 3: Counties with major seaports by period of container adoption

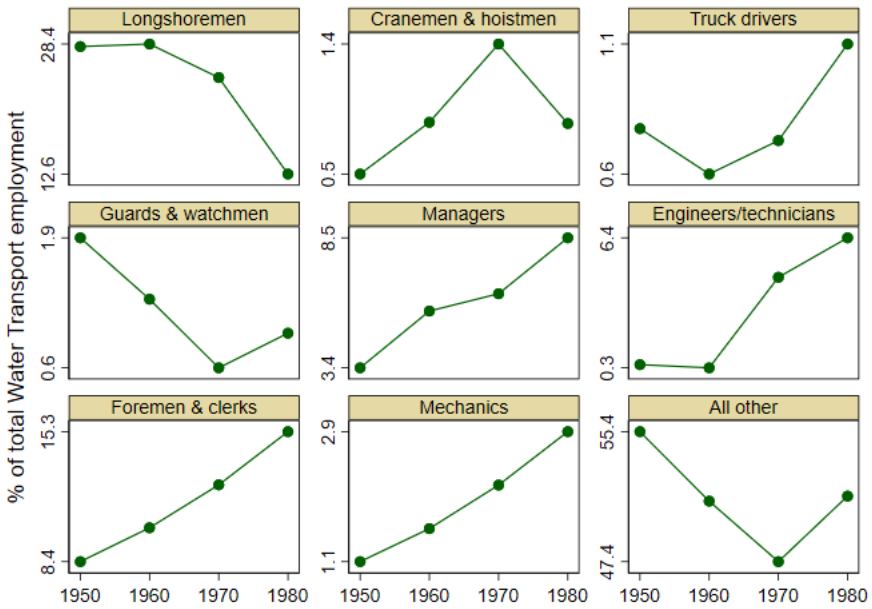


Notes: Includes only counties with ports on oceanic coasts. Port locations and containerization timing from Brooks et al. (2021).

Containerization reallocated shipping activity to concentrate in fewer, larger ports (Hall, 2009). Ocean transshipment was historically a 'last-mile' business: since waterborne transport was much cheaper than land-based transport, goods were typically shipped along water for much of their journey, as near as possible to their final destination (even after the advent and rapid expansion of railway networks) (Levinson, 2006). This meant that ports—the locus of ocean transshipment—were distributed across coastlines roughly in proportion to the nearby commercial and consumer populations they primarily served. This is illustrated by Figure 3, which shows all ocean coastal counties with ports that did not containerize in yellow and counties with ports that did containerize coloured by the period of adoption. Historically large ports such as New York City, San Francisco, and Boston that containerized late, or never, experienced fewer visits from cargo ships and therefore relatively less demand for their transshipment services.

The shift of ocean transshipment from a labor-intensive to capital-intensive industry (Monaco and Olsson, 2005) entailed changes in the number and types of workers required. Figure 2b shows how total employment in the US Water Transport industry (where Marine Cargo handling is the largest subindustry) fell drastically (by about one-third) in the decades following containerization, even as total cargo shipments surged. Dockworkers in ports with declining cargo volumes could not

Figure 4: Total share of water transport employment in select occupations by year



Notes: US totals. Occupations of employed individuals in each census sample from Ruggles et al. (2022). Select occupation groups defined as following: Engineers/technicians (mechanical-engineers, engineers (nec), testing-technicians, technicians (nec), professional, technical and kindred workers (nec)); Foremen & clerks (bookkeepers, shipping and receiving clerks, salesmen and sales clerks (nec), clerical and kindred workers (n.e.c.), foremen (nec)); mechanics (mechanics and repairmen (nec), machinists, automobile-mechanics and repairmen).

easily work at in-demand ports because their seniority-based hiring did not transfer to other piers even in the same city. For example, hiring on Manhattan piers declined by 10 percent from 1961 to 1966 while increasing by over 45 percent in nearby Port Newark-Elizabthport (Goldberg, 1968).[10] The composition of employment also changed. Figure 4 shows the share of Water Transport employment between 1950 and 1980 for select occupations.[11] The share of workers employed as longshoremen decreased steadily with the onset of containerization while the share of workers employed as engineers/technicians, mechanics, and clerical workers increased steadily. Increased containerization was also associated with smaller shares of guards/watchmen, likely due to the vastly decreased risk of theft from shipping goods in containers rather than as break bulk cargo (Levinson, 2006). Containerization was also associated with a 'de-casualization' of longshore and stevedore employment. Historically, as in much of the world, longshoremen in the US had been hired daily based on whichever ships were in port (Donovan, 1999). The smaller number of workers required in a containerized port meant owners preferred having fewer 'steady men' employed for regular hours on a scheduled basis, especially as the tasks involved with longshoring became more technical and required higher skill levels (e.g. operating a large crane) (Monaco and Olsson, 2005; Levinson, 2006).

Despite their irregular employment patterns, longshoremen in the US were very well-organized historically (Donovan, 1999), in part due to their high degree of bargaining power given the "costliness of dock delays" (Ross, 1970). There have been two large dockworker unions since the 1930s: the International Longshoremen's Association (ILA) representing dockworkers in ports along the Atlantic and Gulf coasts and the International Longshore and Warehouse Union (ILWU) in Pacific Coast ports (Cole, 2017). Since they had split apart in 1937, these unions had an acrimonious relationship marked by attempted poaching of locals and public disputes (Levinson, 2006). This likely severely limited their ability to coordinate and prevent containerization from entering any U.S. port.

The unions also differed in their organizational structures and bargaining arrangements, with consequences for their ability to navigate the threat of containerization. The ILWU negotiated

[10]Eventually, declines in transshipment services also reduced manufacturers' incentive to locate near non-containerized ports that no longer served as reliable sources of traded inputs or means to export their products (Levinson, 2006).

[11]As detailed below, the census did not include an industry category specifically for waterborne transshipment services. An alternative data source, the County Business Patterns, does however report employment counts for establishments in a "Marine Cargo Handling" (earlier titled "Stevedoring") sub-industry, which, in coastal counties that report counts for both the industry and sub-industry, made up 63% of Water Transportation employment in 1959.

a single contract for all Pacific ports (Bridgman, 2024) and was relatively centralized, while the ILA was far less centralized with rivalries between union leadership and locals (Ross, 1968). This reflected well-publicized corruption scandals within the union leadership as well as the ILA's large size and substantial variation among ports (Cole, 2017). Aside from being "riven with factional differences" (Ross, 1970), these internal tensions resulted in contract differences among locals in Atlantic and Gulf coast ports that bargained separately (Goldberg, 1968). For example, dockworkers in New York, Boston, and Hampton Roads voted to end a 1972 strike but those in Philadelphia and Baltimore rejected theirs until much later because of insufficient wage guarantee payments (BLS, 1980). During an earlier ILA strike, in 1965, an employer-side negotiator for the port of Savannah, Georgia lamented that "something created in New York" was causing them trouble.[12] These internal governance issues and variation within the ILA made it more difficult for employers to bargain with compared to the ILWU, whose more centralized structure of the ILWU meant employers believed "the union could be relied upon to deliver the fruits of any agreement." (Ross, 1968)

These unions approached the threat of containerization displacing jobs very differently, with the ILWU's "provision-ridden acceptance" contrasted with the ILA's "stubborn resistance" (Ross, 1970). The ILWU conducted an extensive study of trends in shipping and the implications of containerization for longshoring and "concluded that new methods and machines would be introduced no matter how great the effort by the membership to resist change." (Schwarz-Miller and Talley, 2002). The result was the 1960 Mechanization and Modernization Agreement, which allowed employers to introduce new technology and modify work rules in exchange for compensation in the form of at least 35 hours per week of guaranteed pay, limited profit sharing, and pensions for voluntary early retirement for long-serving longshoremen aged 62 to 65 (when they qualified for Social Security) (Fairley, 1979). This reflected the employer's approach of sharing productivity gains 50-50 with the ILWU (Monaco and Olsson, 2005).[13] However, the agreements mainly compensated a majority of established union members over more marginally-attached dockworkers and younger members (Reagan, 2019).

The ILA also understood the threat of containerization, and was ostensibly willing to negotiate for container adoption if its members could share the gains (ILA, 1959). However, the union's weak

[12] Quote from *Savannah Evening Star*, January 11, 1965.

[13] Later, the employers instead decided to buy out work rules to ensure increased productivity, which saved them as the amount of containerized freight increased: by 1970 the estimated productivity gains were $120 million, compared to $29 million of early retirement and job guarantee payouts (Monaco and Olsson, 2005).

degree of centralization—that is, leadership's control over union locals—required it to prioritize job security for all and prevented it from making credible bargains with employer associations on the east coast. As a result, the ILA strongly criticized the ILWU's accommodative approach, arguing that "the West Coast sold their men out, but here on the East and Gulf Coasts, we don't do that... if we have to fight, we'll do so." (Talley, 2002). The ILA also believed that job buyouts would undermine its political power by reducing union membership. Although eventually forced by an arbitrator to accept minuscule employer payments (which were not distributed to workers) in exchange for allowing containerization, the ILA struggled to hold up its side of the bargain and engaged in several major strikes to protect longshore jobs (Ross, 1968).

I return to differences in each union's centralization and consequent bargaining outcomes regarding the containerization in Section 5 when examining their influence on the timing of container adoption across ports.

3 Data and measurement

I combine data on containerization timing and channel depth by port with aggregate dockworker employment by county and newly-digitized data on the volume of container-suitable cargo handled by each port. Each source is discussed below.

The analysis focuses on 90 seaports, restricting the sample to ports on ocean coasts due to different trends affecting inland ports in this period (e.g. the construction of the St Lawrence Seaway) and the generally larger volume of transshipment activity at coastal ports. These ports are geolocated using data from Brooks et al. (2021) and matched to counties in the aggregate and individual labour market data and ports listed in USACE (1953). I focus on the period from the early 1950s, when sufficiently detailed statistics on dockworker employment and port cargo volumes begin, until 1997, when increasingly larger cargo boats greatly increased the importance of depth, rather than container adoption, on the amount of transshipment business ports attracted. Table 1 provides summary statistics on the three different data samples used in this analysis.

Table 1. Summary statistics

(a) Time-variant port-level variables

	N	Mean	Std.Dev.	Min	Max
Employment, Marine Cargo Handling	2010	1077.56	2357.27	0.00	27524.00
Employment, all Water Transport	2350	1975.88	4468.96	0.00	72378.00
Containerized competition faced by port	2898	1.61	1.41	0.00	6.45
Tons of container-suitable cargo (millions)	2028	2.10	4.57	0.00	41.77
Value of container-suitable cargo (millions)	246	397.52	1380.95	0.00	17101.26

(b) Time-invariant port-level variables

	N	Mean	Std.Dev.	Min	Max
Ever-containerized	90	0.43	0.50	0.00	1.00
Containerized by 1960	90	0.07	0.25	0.00	1.00
Containerized 1961-1970	90	0.17	0.37	0.00	1.00
Pacific	90	0.32	0.47	0.00	1.00
% ILA union density, 1950	61	6.88	15.39	0.00	100.00
% ILWU union density, 1950	29	2.14	4.25	0.00	20.02
% Non-HS ILA or ILWU density, 1950	90	5.35	13.05	0.00	100.00
% Non-BA ILA or ILWU density, 1950	90	5.18	12.86	0.00	100.00
Port shallowness, 1953	88	3.16	1.45	1.00	8.00
% Land scarcity, 1955	90	35.82	20.29	2.34	81.52
ln(CargoTons), 1953	86	-1.93	2.23	-9.36	3.00
Containerized competition, 1960	90	0.39	0.29	0.02	1.08
% Manufacturing emp., 1953	90	38.75	17.86	0.00	71.44
% Overall predicted union density, 1953	90	34.22	7.05	0.00	56.62

Notes: Panel (a) sample includes annual observations for 1951 to 1997 for all major coastal ports where county has non-zero initial year (1951) total Water Transport employment. Marine Cargo Handling employment is only separately reported starting in 1959. Containerized competition is an inverse distance-weighted measure of other ports that had containerized. Cargo data is available only for 1953 to 1985. for all counties with major coastal ports. Container-suitable cargo is defined as share of cargo tonnage made up by products that were reported as feasible to ship in a container in 1968, as reported by El-Sahli (2013). Cargo value estimated from tonnage by product using data on average dollar value per ton of product imports and exports in 1970 from OECD (2022). Panel (b) sample is cross-section of ports. Union density measures are number of dockworker union local members, for the East Coast ILA and/or the West Coast ILWU, as a percentage of all employed individuals in port counties with less than a high school or college education. Port shallowness is 8-level scale with smaller values for deeper ports. Land scarcity share of area within 10km of ports that cannot be built on. Manufacturing employment share is the percent of a county jobs in the manufacturing sector in 1953. All-economy predicted union density is the expected overall county union density in 1953 based on its industry employment distribution and national industry unionization rates.

3.1 Containerization and port characteristics

Information on the universe of US ports that existed as of 1953, as recorded in the *World Port Index*, is drawn from Brooks et al. (2021).[14] This includes the latitude/longitude coordinates of each port, which was used to geolocate each port in a 1960 county boundary, as well as the depth of each port in 1953 before containerization. It also includes the year of container adoption, drawn from the *Containerization International Yearbook* editions from 1968 and 1970 to 2010. A port is deemed to have containerized when it has invested in installing special infrastructure and equipment to "handle shipping containers that enables their movement in and out of ship and onto a train or a truck," consistent with industry definitions (Brooks et al., 2021). I aggregate to the county level using the earliest year of containerization of any port in the county and the maximum port depth and then combine certain counties to match geographical aggregations in other datasets.[15] This results in 90 different ports in my data, 39 of which containerize by 1997.

3.2 Volume of container-suitable cargo handled by port

I argue that containerization impacted the amount of total cargo transshipment business at every port, including those that did and did not adopt containers. This requires data on the throughput volume at each port of only goods that could potentially be transported in a shipping container or as break-bulk cargo. I first digitize tables on freight cargo volume at each seaport from annual reports published starting in 1953 by the United States Army Corps of Engineers titled *Waterborne Commerce of the United States* (WCUS) (USACE, 1953). These provide the total number of short tons (2,000 lbs) that travelled through each port in each year from 1953 to 1985, including both foreign trade as well as domestic coastwise and internal waterway trade. I manually crosswalk ports listed in the WCUS to counties used in my other data sources.

However, not all products that are shipped via ocean are possible to ship inside a container (e.g. crude oil). In order to focus only on handling activity of 'container-suitable cargo' I also digitize tables from the 1953 and 1970 WCUS on the volume of freight of each product at each port, with product codes then crosswalked to the SITC Rev. 2 classification. I then use data from a 1968

[14] Special thanks to Nicolas Gendron-Carrier for sharing this data. An alternative version has since been uploaded to ICPSR (Project 199582).

[15] Groupings include all New York City counties with Bergen and Hudson, NJ; Gloucester and Camden, NJ; Brunswick and New Hanover, NC; Norfolk and Suffolk, MA; Penobscot and Hancock, ME; Solano and Sacramento, CA; Orange and Los Angeles, CA; Liberty, Long, and McIntosh, GA; and several Virginia independent cities combined into their adjoining counties.

assessment of which products are feasible to ship in containers (NMC, 1969), listed in El-Sahli (2013), to calculate the share of total cargo volume at each port composed of container-suitable products. Finally, to estimate the annual container-suitable volume of shipments (in tons) handled at each port, I scale the total tons of cargo at each port by the annual share of tons in container-suitable products.[16] I also use data from OECD (2022) on the annual dollar value per ton of foreign trade (imports/exports) in each product to estimate the total value of container-suitable products handled in each port in 1953 and 1970.[17].

3.3 Labour market outcomes

A key measure of interest is aggregate annual dockworker employment in each seaport. The total number of dockworkers employed in each county and year from 1951 onwards is drawn from historical reports of the U.S. Census Bureau *County Business Patterns* (CBP) digitized in Eckert et al. (2022, 2020). From 1959 onwards, the CBP includes data for the granular four-digit SIC industry "Longshoring and Stevedoring", later renamed "Marine Cargo Handling" (SIC code 4463). However, before 1959 the CBP only includes county-industry-year employment counts at the level of the coarser two-digit SIC sector for "Water Transportation" (SIC 44). I use both definitions of dockwork employment in the analyses below. This is because even after 1959, many counties with few Marine Cargo Handling establishments are only included in the total Water Transportation counts due to confidentiality concerns.[18] The employment count in a county-industry-year is based on the number of employees during the pay period that includes March 12 of the year, summed across all establishments in a county in that industry.

The CBP is a valuable data source but with certain limitations. Certain counties are grouped together before 1964, which for consistency then requires these counties to be grouped together for all years of the analysis. Establishment employment is defined only on the extensive margin, meaning it is not possible to analyze how total worker-hours evolved with changes in labour demand. It is not clear how exactly businesses reported their employee counts in an industry with many casually-employed workers. For example, it is not clear whether these counts include dockworkers

[16] Annual shares of container-suitable cargo for each port were calculated for 1953, 1970, 1977, and 1985 from WCUS tables. The share of container-suitable cargo at each port in other intervening years was estimated by linear interpolation.

[17] Future research can use this along with data on national ad-valorem freight-handling rates from Bridgman (2024) to estimate port revenues

[18] However, establishment counts are not included in the Eckert et al. (2022, 2020) data.

who reported to their workplace daily to collect 'job guarantee' payments during this period under the mechanization agreements but did not actually work any hours.[19] Finally, there is other unexplained 'spikiness' observed in the data, likely due to select establishments relocating between counties, switching industry classifications, or not reporting in the CBP in a given year. For the aggregate employment analyses below, I remove any port-year observations with zero employment at established ports before 1975, after which the CBP measurement and reporting quality appears to substantially improve.

3.4 Dockworker union density

As discussed above, both contemporary and retrospective analyses emphasized the role of dockworker labour unions in shaping the adoption of containers by ports. One way to operationalize the role of these unions is through the degree of bargaining power held by dockworkers in each port at the advent of containerization. This can be proxied by dockworkers' local union density, defined as the ratio between the number of dockworkers union local members in a port and the number of non-union dockworkers (or potentially substitutible workers) in that port. For the numerator, I follow recent work by Medici (2024); Downes (2024); Schmick (2018) and digitize proceedings of the ILWU and ILA 1947 and 1955 conventions that include lists of delegates from each union local in attendance and their voting power (ILWU, 1955; ILA, 1955). Delegate counts can be translated to estimates of locals membership based on union representation rules whereby each local received 1 vote for each 100 members. Union locals not represented at the convention have their membership counts listed. For the denominator, I attempt to capture the total pool of *potential* longshore workers at each port in order to calculate the bargaining power of those who are union members. My primary measure is the number of employed individuals with less than a high school education in a port county as of the 1950 census. Alternatively, I define this denominator as employed individuals without a college education. According to the 1950 Census, 98.0% of employed longshoremen in counties with a major coastal port had less than a high school education (educational attainment under grade 12) and 99.9% had less than 4 years of college education.[20]

[19] See for example an account from the port of Brooklyn in 1983: https://www.nytimes.com/1983/06/23/nyregion/guaranteed-wage-is-crux-of-pier-economics.html

[20] An additional measure available for future research is each union locals' representation on committees of the convention, which could be indicative of the local's alignment to the 'international' union organization and therefore its coordination with other dockworker union locals.

3.5 Competition between ports from containerization

Compared to break bulk shipping, containerized cargo transshipment required fewer dockworkers to transfer each ton of cargo freight onto or off a ship—a direct labour displacement effect of this technological change. These large labour productivity gains for transshipment services due to containerization translated to substantial cost savings for ships loading and unloading at a containerized port. Transshipment services provided at a seaport are a tradeable service: cargo ships have some degree of flexibility over which port to stop at and unload their cargo for transportation onward to its final destination onshore, especially with improvements to the highway and railway system in the mid-20th century. Containerized ports could therefore attract transshipment business away from non-containerized ports. For example, Levinson (2006) highlights the cases of Newark/Port Elizabeth, New Jersey attracting shipping business away from elsewhere in the Port of New York (particularly Manhattan and Brooklyn) and Oakland, California attracting shipping business away from the Port of San Francisco. As the interstate highway system was built-out, ports on one coast even competed with ports on the other side of the US (Hall, 2009).

To estimate the relationship between dockworker employment in a port and containerization elsewhere, I construct a 'market access style' distance-weighted measure of the degree of containerized competition faced by port c in each year t based on containerization in all other ports $j \in J$ as

$$ContainerCompetition_{ct} = \sum_{j}^{J} \left((TradeCosts_{cjt})^{-\theta} \mathbf{I}\left(Containerized_{jt}\right) \right) \tag{1}$$

where $TradeCosts_{cjt}$ is a measure of iceberg trade costs between c and competing port j, based on the cost of transporting cargo by land in each year (Jaworski and Kitchens, 2019). This exploits exogenous variation over time in highway expansion as well as other time-varying components of trade costs: truck driver wages, fuel costs, and the mileage of heavy trucks.[21]

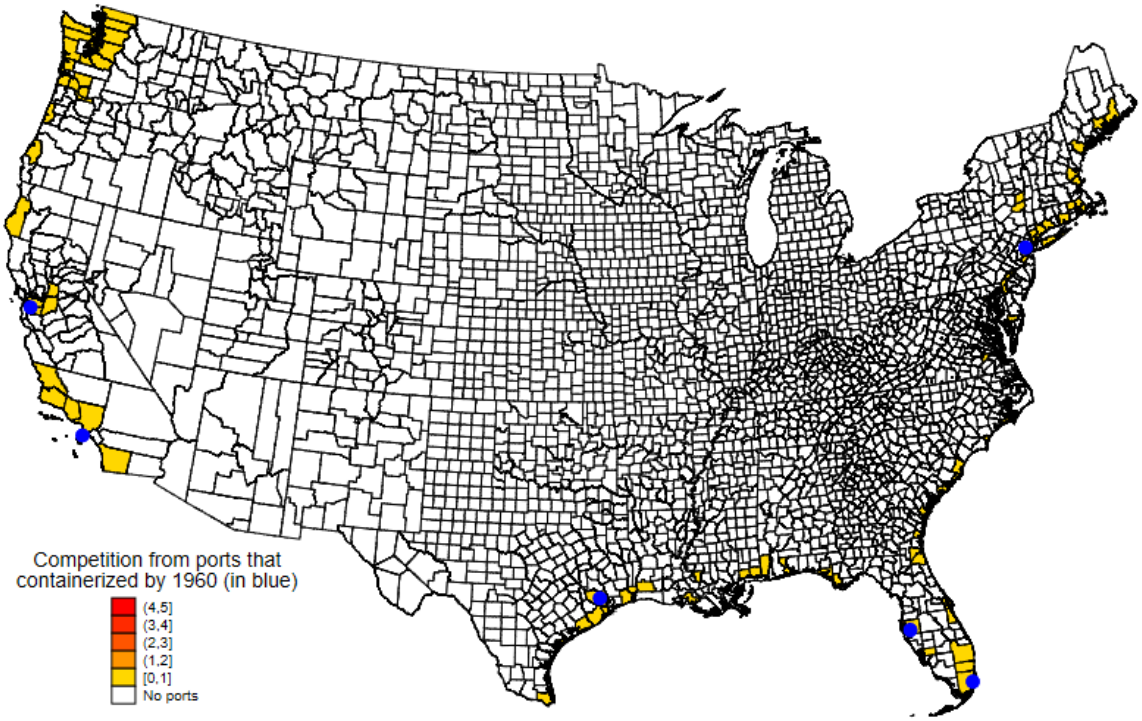
$\mathbf{I}\left(Containerized_{jt}\right)$ is an indicator equal to one if there was a containerized port in county j in year t and zero otherwise. $ContainerCompetition_{ct}$ is increasing in the number of containerized ports across the U.S. and decreasing in the transportation cost from any port c to those containerized ports. Similarly to Cockriel (2024), this term mirrors the reduced form definition of market

[21] See Appendix A.1 for details on the calculation of trade costs.

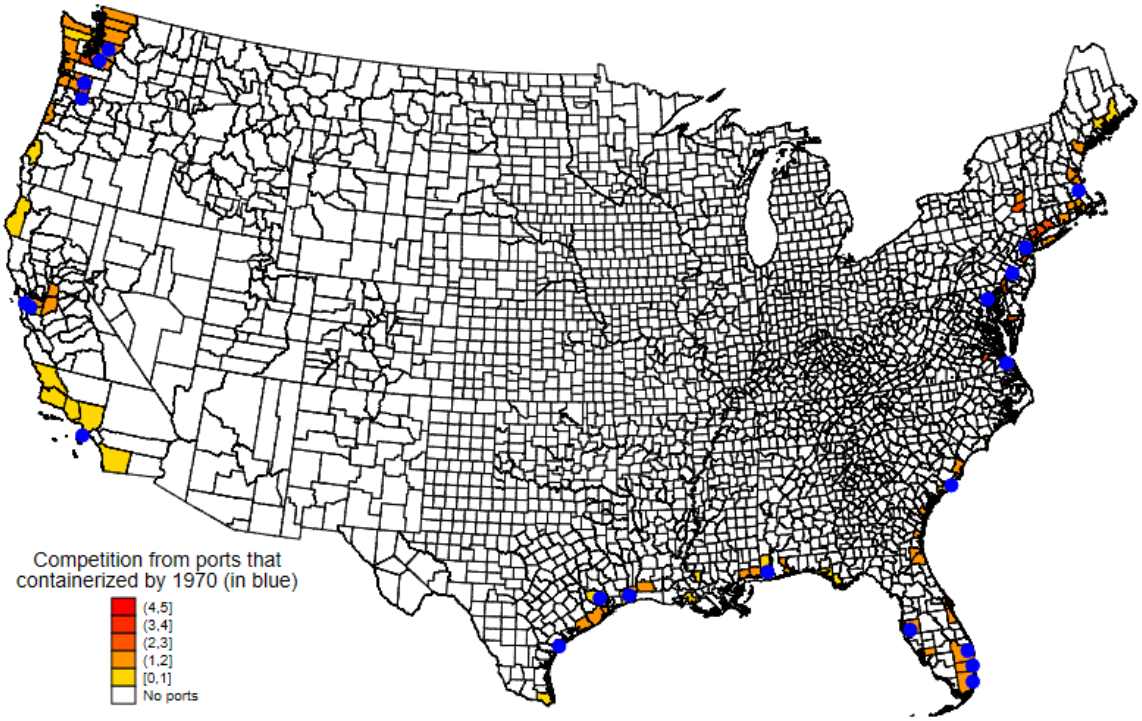
access in Donaldson and Hornbeck (2016) but replaces access to populations with access to a new technology that affects employment elsewhere. I use a trade elasticity value of $\theta = 8$, following Jaworski and Kitchens (2019) who study a similar period and location and report that this value is within the range reported in the international and domestic trade literature.

No ports faced containerized competition before adoption in the US began in 1956. Figure 5 maps all containerized ports (represented by blue dots) and the corresponding level of containerized competition (shaded from yellow to red) at each ten-year point from 1960 to 1990. In 1960 the median port county had a level of containerized competition of 0.38. The level of competition was highest in Florida, where two counties already had containerized ports and also faced competition from being located in between other containerized ports in New Jersey and Houston. The level of containerized competition faced by all ports increased over time as more ports containerized: the median port county had a level of containerized competition of 1.92 in 1970, 2.77 in 1980, and 3.50 in 1990.

Figure 5: Level of competition from containerization in other ports



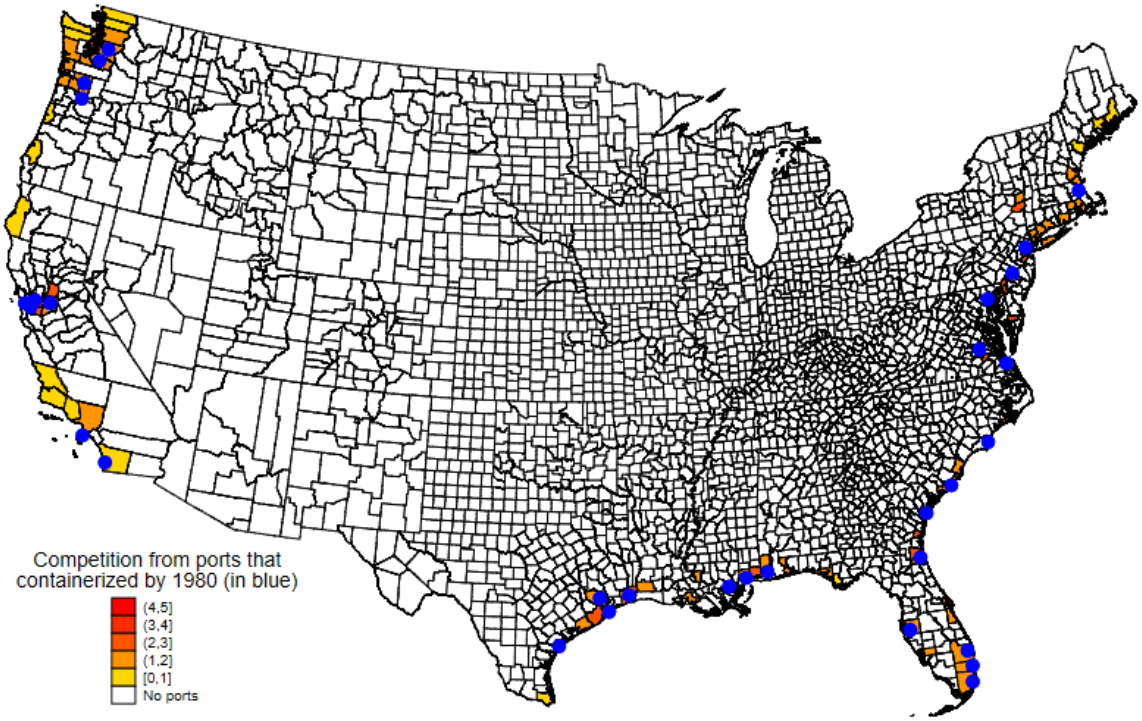
(a) Ports containerized by 1960



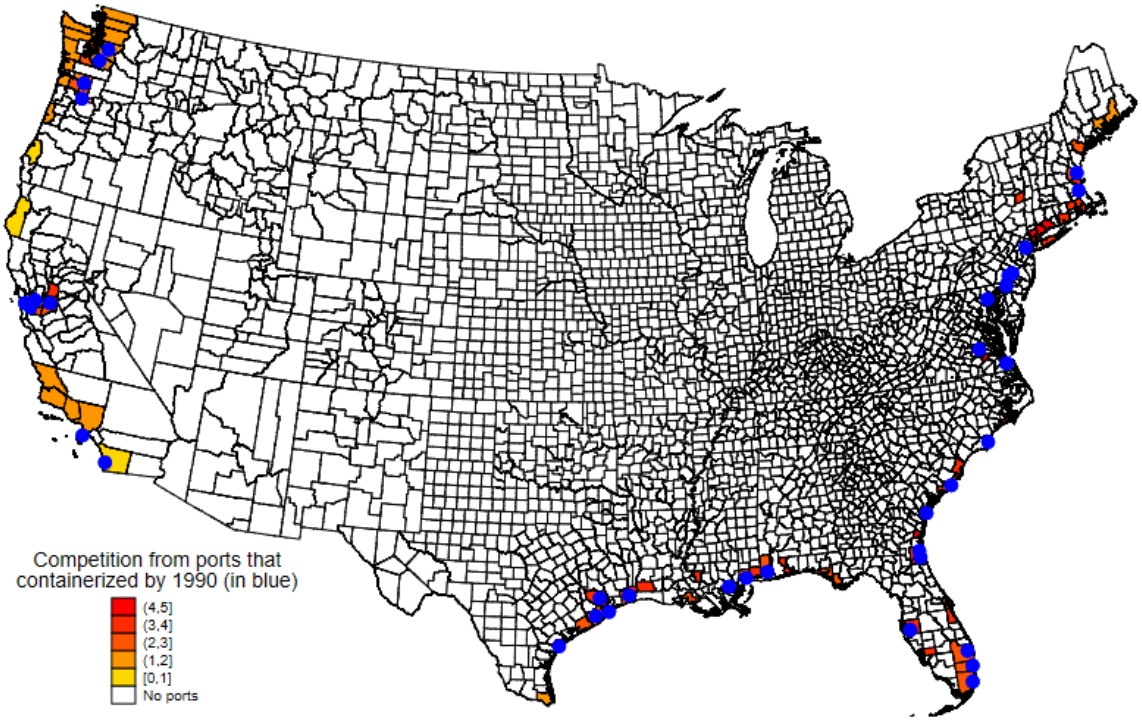
(b) Ports containerized by 1970

Notes: Blue dots represent counties with ports containerized up to and including each year. Containerized competition from other ports is distance-weighted measure of number of other ports that have containerized. Port locations and containerization from Brooks et al. (2021).

Level of competition from containerization in other ports (contd.)



(c) Ports containerized by 1980



(d) Ports containerized by 1990

Notes: Blue dots represent counties with ports containerized up to and including each year. Containerized competition from other ports is distance-weighted measure of number of other ports that have containerized. Port locations and containerization from Brooks et al. (2021).

4 Containerization and dockworker and port firm outcomes

In this section I document the relationships between a port's own containerization, the level of containerized competition it faces, and dockworker labour market outcomes and cargo activity at that port. I first provide descriptive statistics on trends by port. I then use a two-way fixed effects regression analysis to analyze these relationships on an aggregate level, finding that dockworker employment decreased with own-port containerization and containerized competition from other ports, but that a port adopting containers insulated its workers from these declines. The volume of cargo handled by a port also increased following containerization. I next look at the benefits of early adoption in a cross-section of port outcomes. Using a geographic cost shifter IV strategy that follows the recent containerization literature, I find that ports that containerized by 1970 had significantly higher shares of the total US cargo handling market in later years and of total dockworker employment. These results motivate my discussion in Section 5 of the role of unions in the timing of a port adopting containers.

4.1 Port aggregate outcomes

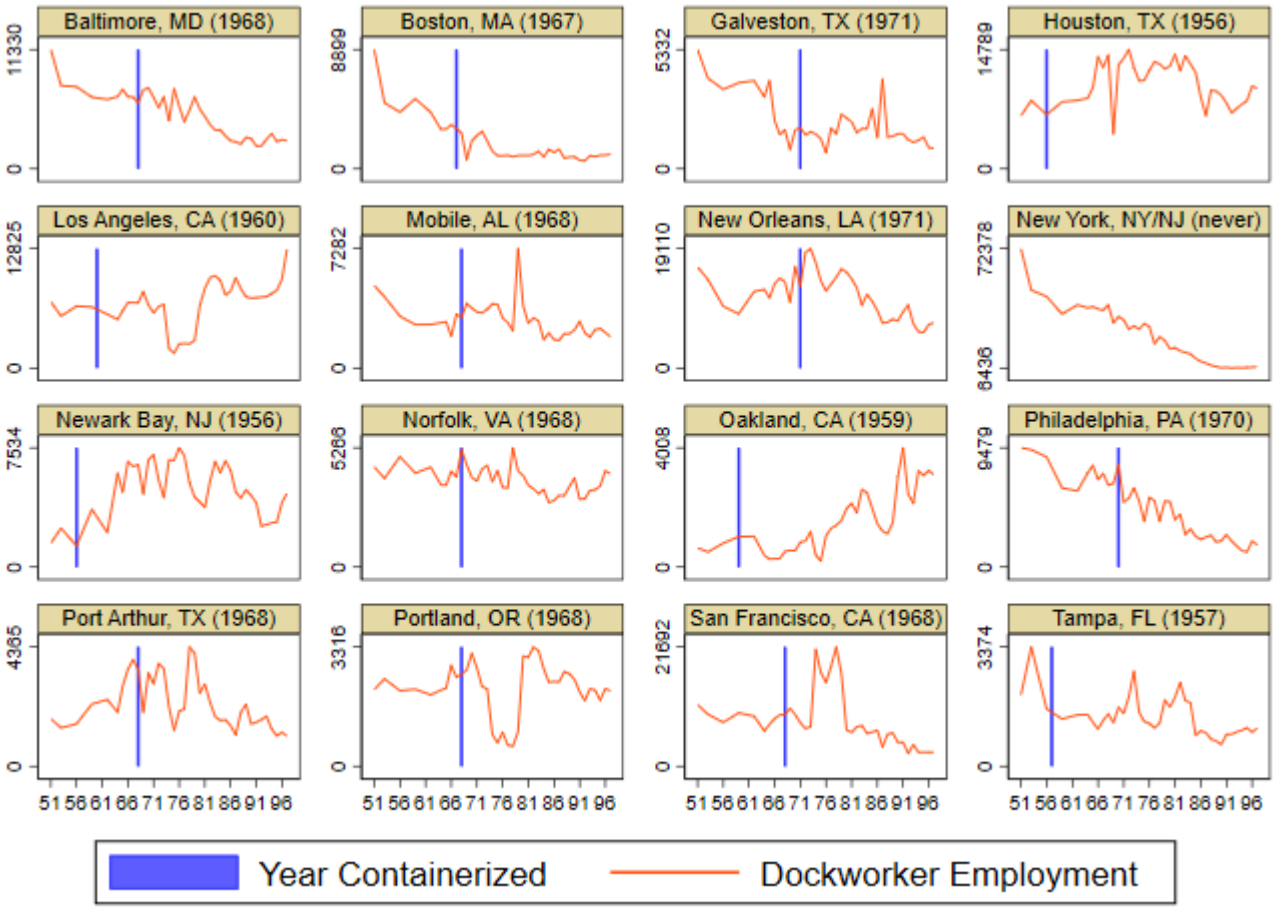
4.1.1 Trends in dockworker employment and cargo volume by port

Total dockworker employment appears to have fallen more at ports that containerized later, or never. Figure 6 plots total annual county employment in the Water Transportation sector for the 16 ports with the highest dockworker employment in 1959 (the first year Marine Cargo Handling is separately reported in the CBP).[22] The vertical blue lines on each plot illustrate the year of container adoption in that port, also indicated in parentheses after the port name. These plots suggest that ports where containers were adopted earlier (i.e. the blue line is further left on the X axis) had smaller declines in dockworker employment. Note however there are large differences in employment levels in each port (obscured by the changing y-axis for each subplot).

Figure 7 illustrates similar trends for the volume of container-suitable cargo handled by each of these ports. Several early-adopter ports (e.g. Newark Bay, NJ; Los Angeles, CA; Oakland, CA; and Houston, TX) experienced increases in cargo volume after containerization. While the downward trend in cargo volume at several late- or never-adopter ports is clear (e.g. Boston, MA; New York, NY/NJ; and Philadelphia, PA) the more limited time span of the current shipping data

[22] Appendix Figure A1 provides these trends for the Marine Cargo Handling subsector.

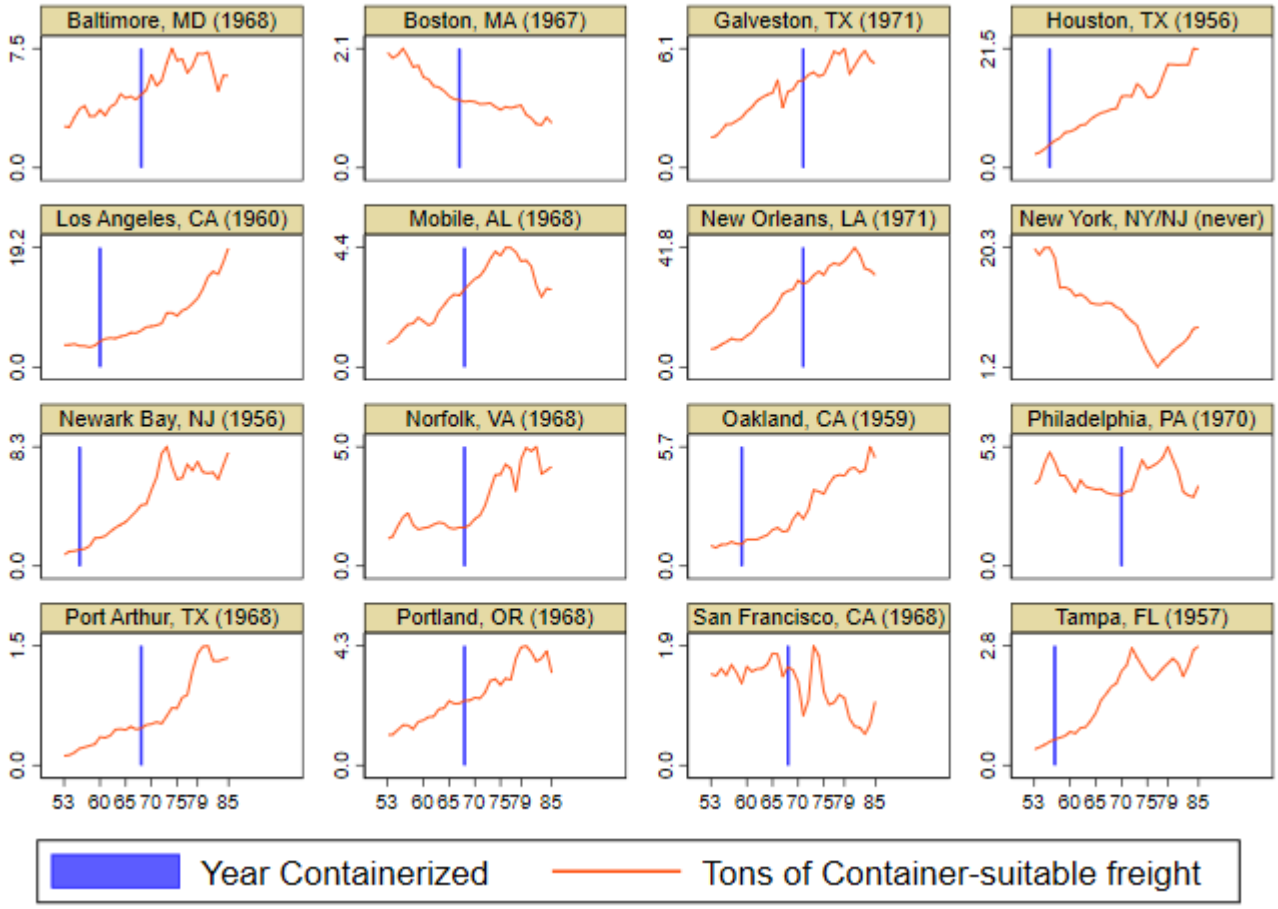
Figure 6: Total water transport employment and container adoption for largest ports



Notes: Dockworker employment is total annual county employment in the Water Transportation sector (SIC 44) from Eckert et al. (2022). Port locations and containerization timing from Brooks et al. (2021).

until 1985 means many declines after this year may not be shown. Furthermore, the extrapolation of 1970 port shares of container-suitable cargo as applied to total annual cargo tonnage for 1971-1985 may artificially inflate the estimates of container-suitable cargo tonnage pictured here, if ports increasingly substituted away from container-suitable products after 1970 (for example, by increasing their shipments of refined petroleum or bulk wheat).

Figure 7: Tons (M) of container-suitable cargo throughput and container adoption by port



Notes: Shown for 16 ports with highest amount of Marine Cargo Handling employment in 1959. Cargo activity from USACE (1953) and product container-suitability from El-Sahli (2013). Port locations and containerization timing from Brooks et al. (2021).

4.1.2 Regression analysis

I estimate the direct and indirect relationships between containerization and annual port dockworker employment and cargo volume in port c in year t in a two-way fixed effects model as:

$$\begin{aligned}\ln(Y)_{c,t} =& \beta_0 + \beta_1 \mathbf{I}(Containerized_{c,t}) + \beta_2 CompetitionContainers_{c,t} \\ &+ \beta_3(\mathbf{I}(Containerized_{c,t}) \text{ x } CompetitionContainers_{c,t}) + \beta_c FE_c + \beta_t FE_T + \epsilon_{ct} \quad (2)\end{aligned}$$

where $\ln(Y)_{c,t}$ represents the two aggregate outcomes of interest: (1) log of annual county dockworker employment in port c, defined as either in the Marine Cargo Handling subsector or the overall Water Transportation sector or (2) the annual volume of container-suitable cargo that travelled through port c. FE_c are port fixed effects, to account for time invariant port-specific factors such as climate and location or the number of Water Transportation jobs outside Longshore services (e.g. local ferry services). FE_t are year fixed effects, included due to the possibility of unobserved factors that affect overall demand for shipping services each year, such as business cycles or the Vietnam War (Levinson, 2006). $\mathbf{I}(Containerized_{c,t})$ is an indicator equal to 1 if port c adopted containerization by year t (an absorbing state) and zero otherwise. $CompetitionContainers_{c,t}$ is a distance-weighted measure of the level of competition port c faced from other ports that have adopted containers by year t, as described in Section 3.5.

Results are provided in Table 2. Panel 2a contains results for dockworker employment. Columns (1) and (3) first provide results from a 'naive' regression of annual dockworker employment on an indicator for whether that county containerized by that year. This yields a positive coefficient (though only statistically significant in column (3)) indicating that, on average, ports that containerize have better aggregate employment outcomes than non-adopter ports—which can be largely accounted for by business stealing. This is shown by the baseline specification in columns (2) and (4), from a regression of employment on the full interaction of containerization and competition. This regression estimates negative coefficients on the indicator for 'own port containerization' and the level of containerized competition from other ports but a positive coefficient on their interaction. This suggests that dockworker employment in a port declines when it adopts containerization or faces greater competition from other ports containerizing, holding each other constant, but that containerization insulates dockworkers from further job loss due to competition. The adoption of

Table 2. Regression of annual port outcomes on containerization and container competition

(a) Dependent variable: ln(Employment)

	Marine Cargo Handling sub-sector		Water Transport sector	
	(1)	(2)	(3)	(4)
I(Containerized)=1	0.450	-0.396**	0.528**	-0.153
	(0.261)	(0.127)	(0.193)	(0.088)
Container Competition		-0.466***		-0.373***
		(0.050)		(0.035)
I(Containerized)=1 × Competition		0.364***		0.213***
		(0.033)		(0.008)
Constant	7.476***	8.613***	8.540***	9.520***
	(0.151)	(0.210)	(0.087)	(0.088)
Port FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Obs.	1393	1393	2342	2342
R-Squared	0.79	0.83	0.90	0.92

Standard errors clustered by Census Division in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01

(b) Dependent variable: ln(Tons of container-suitable cargo)

	(1)	(2)	(3)
I(Containerized)=1	0.510**	0.505**	-0.209
	(0.133)	(0.129)	(0.145)
Container Competition		-0.104	-0.231
		(0.157)	(0.173)
I(Containerized)=1 × Competition			0.472**
			(0.118)
Constant	12.752***	12.861***	12.994***
	(0.031)	(0.150)	(0.172)
Port FE	Y	Y	Y
Year FE	Y	Y	Y
Obs.	2764	2764	2764
R-Squared	0.86	0.86	0.86

Standard errors clustered by Census Division in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01

Notes: Sample for employment regression includes annual observations for 1951 to 1997 for all counties with major coastal ports and non-zero initial year employment (1959 for Marine Cargo Handling and 1951 for total Water Transport). Sample for cargo regression includes annual observations for 1953 to 1985 for all major coastal ports. Independent variables are indicator that county c was containerized by year t as recorded by Brooks et al. (2021), a measure of the distance-weighted competition posed by other ports that had containerized by year t, and their interaction. Container-suitable cargo defined as share of cargo tonnage made up by products that were reported as feasible to ship in a container in 1968, as reported by El-Sahli (2013). Regressions weighted by level of port county initial year employment in dependent variable industries.

containers in a port is associated with a 40% decrease in Marine Cargo Handling employment, with a smaller estimated decrease in overall Water Transportation employment that is not significantly different from zero (though the t-statistic is 1.74). In comparison, a one-unit increase in the level of containerized competition faced by a port (roughly equivalent to moving from the 10th to the 75th percentile in 1970) is associated with a 47% decrease in Marine Cargo Handling employment or again a 37% decrease in overall Water Transportation employment. However, when the port is containerized, increased competition is associated with a 36% increase in Marine Cargo Handling, or a 21% increase in Water Transport employment.[23] For both sectoral measures of dockwork employment, the coefficient on competition is larger in magnitude than on the interaction term, indicating that while a port that containerizes insulates itself somewhat from business stealing, there is still net job loss.

Panel 2b contains results for similar regressions with cargo volume as the dependent variable. This similarly shows a positive coefficient estimate on the containerization indicator when it is the sole explanatory variable, and when also controlling for the level of containerized competition facing the port. This is because demand for cargo transshipment services at a port increases after it containerizes. Column (3) shows a positive coefficient estimate on the interaction of these variables. The magnitude of these coefficients is relatively similar across all three specifications: the tonnage of container-suitable cargo handled by a port increases by about 50% after it containerizes. These results show that the volume of container-suitable cargo handled by a port increases with its own containerization, especially when controlling for the level of competition it faces from other containerized ports. They suggest that there was a benefit to port owners from adopting containers. However, the results are much noisier than the employment regressions. This could be due to the smaller sample period (only to 1985). It also fits with findings by Bridgman (2024) that the benefits of containerization to shippers may have been delayed, resulting in a slower shift to containerized ports from break bulk-only ports.

4.2 Early adoption

The results discussed above indicate that, following containerization, ports did not experience as large declines in employment or product demand as non-containerized ports, and may have even

[23] This positive and statistically significant coefficient on the interaction term could mean that containerized ports that were more centrally located (i.e. closer to other containerized ports), had more opportunities for bilateral shipping relationships and/or business stealing.

gained cargo transshipment business at the expense of rival ports. This is indicative of a first-mover advantage for ports that containerized earlier, and therefore were able to attract cargo transhipment business from non-containerized ports. I next attempt to estimate this more precisely, by focusing on a cross section of outcomes by 1970. By this time, 21 of the 90 major coastal ports in my sample had containerized. I show that 'early-adopter ports' that containerized by 1970 capture a larger share of the total US market for ocean transshipment shipping and that these early-adopter ports have a larger share of total US dockworker employment. This indicates that both firms (ports) and their workers enjoyed a first-mover advantage from early adoption of this automation.

For identification, I use a geographic cost-shifter instrumental variable in a 2SLS approach following recent literature on containerization and city population growth (Brooks et al., 2021; Ducruet et al., 2024). Specifically, I instrument for $\mathbf{I}(Containerized1970_c)$, an indicator equal to one if a port containerized by 1970, with $PortShallowness_{c,1953}$. This is a categorical variable in five-foot increments with smaller values for deeper ports, provided in the World Port Index with data from Brooks et al. (2021). Since container ships require deeper ports than ships carrying break bulk cargo, and since there is a high cost to making an initially shallow port sufficiently deep for container ships, "initial port depth is a key component of the cost of converting a breakbulk port into a containerized port." (Brooks et al., 2021) Initial depth is therefore an "exogenous cost-shifter" that makes it less expensive for a port to reach a certain depth by dredging (Ducruet et al., 2024).

My first stage regression is the following:

$$\begin{aligned}\mathbf{I}(Containerized1970_c) =& \beta_0 + \beta_1 PortShallowness_{c,1953} + \beta_2 CompetitionContainers_{c,t} \\ &+ \beta_3 Y_{c,1953} + \beta InitialConditions_c + \beta CensusDivisionFE_c + \epsilon_c \quad (3)\end{aligned}$$

where $CompetitionContainers_{c,t}$ is the distance-weighted level of container port competition faced by port c in each year t (where t varies with the second stage outcome of interest) and $Y_{c,1953}$ is the value of the second stage outcome of interest pre-containerization. $InitialConditions_c$ is a vector that includes the share of employment in manufacturing in 1953 and the log of population in 1910 and its square (as in Brooks et al., 2021). I include Census Division fixed effects, $CensusDivisionFE_c$. The sample is the cross-section of all ports in each end-year t that I observe the second stage outcome of interest.

In the second stage regressions, I show the effects of early container adoption (by 1970) on

a port's share of total (1) demand for transhipment services and (2) dockworker employment. I regress the outcome $Y_{c,t}$, a port's share of total US container-suitable cargo or dockworkers in year t, on the indicator for container adoption by 1970, the value of the outcome variable in the port in 1953 before containerization, the distance-weighted level of containerized competition facing the port in year t, the vector of initial conditions, and census division fixed effects.

The container-suitable cargo shipments outcome is observed in $t = 1953, 1970, 1977, 1985$, both as a port's share of total tonnage and the port's share of the total cargo value handled by all ports in my sample. The latter leverages port-by-product shipping data combined with trade data from OECD (2022) that contains the average dollar value per ton of each product to estimate the dollar value of container-suitable cargo at each port. The dockworker employment outcome is observed (nearly) annually in the CBP, but to minimize noise (including missing years) in the data I take three-year moving averages and here show results for select years. Pre-containerization employment is the average of 1951, 1953, and 1956 values.

Results are provided in Table 3. They suggest that there was a benefit to both port owners and dockworkers from earlier adoption of containers. Compared to ports that had not containerized by 1970 (the omitted group), early-adopter ports handled a significantly higher share of container-suitable cargo in 1970, 1977, and 1985. In terms of tonnage the coefficient is slightly smaller for 1985, while in terms of cargo value early-adopter ports only had a significantly higher share in 1985 and not in earlier years. For employment, early-adopter ports had a larger share of total employment (across all ports in sample) starting in 1977, with the magnitude growing over time. Results from OLS specifications of these regressions are included in Appendix Section A.3.

These results are indicative of a first-mover advantage for ports that containerized earlier, and therefore were able to attract cargo transhipment business from non-containerized ports. The effects also appear to grow over time.

Table 3. 2SLS regression of % of US total container-suitable cargo and dockworker employment on port container early adoption, instrumented by pre-containerization port depth

(a) Container-suitable cargo handled

	% of US tonnage			% of US value		
	(1)	(2)	(3)	(4)	(5)	(6)
	1970	1977	1985	1970	1977	1985
Containerized by 1970	4.06**	5.54**	3.71**	-6.82	0.76	4.31**
	(1.61)	(2.50)	(1.56)	(7.77)	(3.30)	(1.84)
Competition in end-year	0.24	0.50	-0.04	-1.80	-0.39	0.11
	(0.19)	(0.43)	(0.16)	(1.78)	(0.63)	(0.36)
Pre-containerization (1953)	0.59***	0.25	0.27*	0.39	0.13	0.16***
	(0.16)	(0.22)	(0.15)	(0.24)	(0.27)	(0.04)
Constant	-42.83***	-38.68	-24.71	63.05	2.30	-7.45
	(16.16)	(24.54)	(19.93)	(52.92)	(22.63)	(18.37)
Census Division FE	Y	Y	Y	Y	Y	Y
Port controls	Y	Y	Y	Y	Y	Y
Obs.	86	86	86	84	84	84
R-Squared	0.36	-0.04	0.31	-0.19	0.34	0.32
1st stage F-stat	11.4	12.3	7.5	7.6	9.6	7.6
DV Mean	1.2	1.2	1.2	1.2	1.2	1.2

(b) Water transportation sector employment

	DV: % of total dockworker employment in end-year across all ports in sample					
	(1)	(2)	(3)	(4)	(5)	(6)
	1970	1977	1980	1985	1990	1996
Containerized by 1970	1.66	3.05***	3.24***	4.12***	4.03***	4.45***
	(1.10)	(1.12)	(1.06)	(1.25)	(1.35)	(1.55)
Pre-containerization emp	2.16***	1.96***	1.58***	1.27***	0.89***	0.86***
	(0.11)	(0.22)	(0.21)	(0.19)	(0.15)	(0.14)
Competition in end-year	-0.08	0.53*	0.34	0.19	0.02	-0.02
	(0.22)	(0.29)	(0.22)	(0.17)	(0.20)	(0.17)
Constant	-9.96	-24.76***	-26.03**	-29.77**	-30.75***	-29.36**
	(7.00)	(9.55)	(10.13)	(11.90)	(11.43)	(12.39)
Census Division FE	Y	Y	Y	Y	Y	Y
Port controls	Y	Y	Y	Y	Y	Y
Obs.	68	76	76	76	76	76
R-Squared	0.93	0.72	0.73	0.54	0.46	0.34
1st stage F-stat	6.7	11.7	8.0	7.2	5.8	5.3
DV Mean	1.5	1.3	1.3	1.3	1.3	1.3

Notes: Regressions of each outcome on an indicator of the port having adopted containers by 1970, instrumented by its depth in 1953 (before containerization technology was invented). Each regression is run on the cross-section of ports without any missing variables and includes the following controls: pre-containerization value of the dependent variable; the level of distance-weighted competition from containerized ports in the end-year; the share of employment in manufacturing in 1950, the log of population in 1910, and the square of the latter; and census division fixed effects. In Panel (a) dependent variables are each port's share of total US container-suitable cargo in terms of tons (Columns 1-3) and value (Columns 4-6) in the listed end-year. Port shipments data from USACE (1953) includes foreign, coastwise, and internal trade at each port in tons by product. Cargo-suitable products are a subset of all products, assessed as of 1968 and reported in El-Sahli (2013). Total cargo value estimated from product values (dollars per ton) of US foreign trade in OECD (2022). In Panel (b) the dependent variable is each port's share of total employment in the Water Transport sector (among sample ports) in the end-year listed. Employment counts are three-year moving averages for smoothing and due to missingness, from Eckert et al. (2020, 2022).

5 Unions and port container adoption timing

The above results establish that containerization displaced labour at ports that adopted as well as ports that competed with adopters, but that both early-adopter ports and their dockworkers enjoyed a first-mover advantage. Considering these dynamics, how did dockworkers respond to the prospect of container technology, and how did they shape their port's decision to adopt?

The historical literature on containerization argues that differential adoption patterns across ports were driven in part by unions' stances against or in favor of the new technology (Levinson, 2006; Monaco and Olsson, 2005; Ross, 1970). The two major unions, one on each coast of the U.S., took very different approaches to the threat of containerization in the 1950s and 1960s. While the ILA attempted to prevent container adoption in East Coast ports it had organized, the ILWU bargained to allow containerization of any Pacific Coast ports in exchange for the employers "buy[ing] out the property rights of registered workers" (Goldberg, 1968). Furthermore, within each union, ports varied in the strength of their local organizing, potentially influencing whether and when the port adopted containers. After exploring why the unions' stances on containerization diverged, in an empirical analysis I focus on differences in bargaining power across ports *within* each union that I argue impacted the port local's ability to enact its union-wide stance against or in favor of containerization. I document a non-linear relationship between worker bargaining power and automation adoption, controlling for a range of potential confounders. Stronger local bargaining power increased the probability of early adoption in the Pacific, where the coast-wide union reached a bargain to facilitate container adoption in exchange for payments, but decreased early adoption in Atlantic and Gulf coast ports where the union had taken a coast-wide stance against containers. This meant there was a first-mover advantage enjoyed by more unionized ports in the Pacific (as well as a first-mover advantage in East Coast ports where the local union could not prevent containerization). This adds nuance to typical views of worker power as uniformly decreasing the likelihood of technological adoption, especially for labor-saving technologies, (Lindbeck and Snower, 2001; Rosenberg and Curci, 2023; Card et al., 2014) or conversely where it may increase technological adoption (Tauman and Weiss, 1987; Beath et al., 1989; Freeman and Medoff, 1984).

5.1 Theoretical and historical analysis

I first explore why the two coast-wide longshore unions took different stances on the prospect of shipping container adoption at ports whose workers they had organized. I provide a simple game theory model in line with the historical accounts in Section 2 that illustrates multiple potential equilibria stances on an automation. In this game, each union is best off cooperating to block all containerization, but can instead deviate to facilitate adoption in exchange for private benefits, with the possibility of having different weights on the payoffs from each action. I first set up the model and then describe how both it and the historical accounts highlight three factors that explain the unions' different stances and are otherwise unrelated to ports' potential gains from containerization: (1) their lack of cooperation against the threat of containerization; (2) divergent beliefs about the likelihood of indirect job displacement from containerization; and (3) differences in their ability to effectively bargain with their employer association counterparties due to different degrees of centralization and negotiating histories.

The model is a non-repeated (one-off) game where two unions, each representing a single firm (port) in competition with the other firm, decide whether to oppose or facilitate adoption of an automation technology (containers) at their firm. In this model the unions have complete hold-up power, i.e. they can fully prevent or enable adoption of the automation by their firm, although each union may not believe that other is able or willing to prevent adoption. It is assumed that firms want to adopt the technology and are willing to pay their workers some compensation to facilitate (rather than obstruct) adoption.

Payoffs to each union are based on the total income of the workers they represent. One component of this income is wages from employment at the firm. Adoption of the automation reduces the labor intensity of the product sold by the firm (cargo transshipment services) and hence reduces the workers wages from W_H to W_L. Productivity also increases from adoption of the automation at the adopting firm. If only a single firm adopts, it steals some amount of demand D away from the non-adopting firm. This change in demand also flows through to workers earnings. The final component of earnings is a compensation payment C that workers at an adopting firm receive for facilitating adoption of the automation.

Unions preferences over each outcome in Table 4 are based on their beliefs over the relative size of their payoffs. It is possible that for both, the largest payoff may be the status quo, where both oppose the technology and prevent its adoption at all forms (no ports containerize). However,

this outcome may still not be possible. Importantly, this would require cooperation between both unions. As the historical evidence in Section 2 shows, the ILA and ILWU had a bitter relationship marked for example by accusations of selling out and attempted poaching (Levinson, 2006), which severely limited their chances at coordinating to prevent containerization from occurring at any U.S. port.

It is also possible that, if Union A *believes* D and C are sufficiently large then Union A will have preferences such that

$$W_L^A + D^A + C^A > W_H^A > W_L^A + C^A > W_H^A - D^A$$

At the same time, Union B may *believe* that D and C are so small that Union B will have preferences such that

$$W_H^B > W_H^B - D^B > W_L^B + D^B + C^B > W_L^B + C^B$$

These beliefs are in line with historical accounts of each union's approach to containerization. The Pacific coast ILWU (Union A in this case) conducted an extensive study of how containerization would affect shipping trends across ports, and as a result recognized the strong likelihood of a first mover advantage (Goldberg, 1968). This can be represented in the model as belief in a large value of D. In contrast, the East coast ILA (Union B) appeared relatively unconcerned about container adoption at the Ports of Newark and Houston in 1956, believing these "new operations" would not reduce any existing union employment (Ross, 1970), in line with believing D was small.

Differences in beliefs about the size of C are also in line with each union's prospective bargained compensation outcomes. The unions differed in their organizational structures and bargaining arrangements, affecting their ability to bargain to share the gains from containerization. The ILWU's relatively centralized structure meant employers believed "the union could be relied upon to deliver the fruits of any agreement." (Ross, 1968) As a result, it was able to negotiate the 1960 Mechanization and Modernization Agreement to allow ports to introduce containers in exchange for compensation—a large value of C. Internal governance issues and lack of coordination within the ILA made it more difficult for employers to bargain with, even though it was ostensibly willing to negotiate for container adoption if its members could share the gains (ILA, 1959). Lack of centralization by the union leadership and a poor negotiating history marked by mutual distrust and several large strikes in the previous decade prevented the ILA from making credible bargains

with employer associations on the East coast, reducing the size of C its union members expected.

As a result of these different beliefs, in this game Union A will decide to facilitate adoption of the automation technology while Union B will oppose it, leading to the outcome in the top right of Table 4. This is in line with the historical experience of containerization, where the ILWU facilitated adoption and the ILA opposed it.

Table 4. Diagram of union stance on automation adoption game

		Union A	
		Oppose	Facilitate
Union B	Oppose	(W_H, W_H)	$(W_L + D + C, W_H - D)$
	Facilitate	$(W_H - D, W_L + D + C)$	$(W_L + C, W_L + C)$

5.2 Empirical analysis

Taking into consideration these different union stances towards containerization, the empirical analysis focuses on variation in union local bargaining power across ports. Rather than adoption being uniformly more likely to occur in ports with weaker union representation, as predicted by models emphasizing the investment effects of union hold-up power (Grout, 1984; Card et al., 2014; Cardullo et al., 2015), I argue that union locals with more bargaining power would be better placed to enforce whichever position towards containerization their union had taken coast-wide. Differences in dockworker bargaining power within ports on the same coast (all represented by the same union) impacted the ability to uphold, and make credible, their unions' bargains with firms to support containerization—or their ability to oppose it. Specifically, I argue that differential local bargaining power influenced the ability of ILA workers to successfully prevent containerization at their port as well as whether cooperative ILWU workers could enforce their side of an adoption bargain with employers.

To test this, I estimate the following linear probability model regression of early containerization

(by 1970) on a variety of ex-ante characteristics of the port:

$$\begin{aligned}\mathbf{I}(Containerized)_{c,1970} =& \beta_0 + \beta_1 ILADensity_{c,1950} + \beta_2 ILWUDensity_{c,1950} + \beta_3 \mathbf{I}(PacificPort)_c) \\ &+ \beta_4 PortShallowness_{c,1953} + \beta_5 LandScarcity_{c,1955} \\ &+ \beta_6 \ln(CargoTons)_{c,1953} + \beta_7 CompetitionContainers_{c,1970} \\ &+ \beta_8 OverallUnionDensity_{c,1953} + \beta_9 ManufacturingEmp_{c,1953} \qquad (4) \\ &+ \beta InitialConditions_c + \epsilon_c \qquad (5)\end{aligned}$$

where the dependent variable is an indicator of whether port c adopted containerized shipping by 1970.

The main explanatory variables of interest are measures of the ex-ante local membership density of each dockworker union: $ILADensity_{c,1950}$ on the Atlantic/Gulf coast and $ILWUDensity_{c,1950}$ on the Pacific coast.[24] These union density measures are calculated as union local members as a percentage of the pool of potential members. This denominator is defined mainly as all employed individuals in the port county with less than-high school education in 1950 across all industries. This is motivated by the fact that in 1950, 98% of longshoremen in major seaports had less than a high-school education. Alternatively, in Column (4) the denominator is defined as all employed individuals with less than-college education (see detailed discussion in Section 3.4.). The goal of these union density measures are to capture the bargaining power of the union local within a port. The ability of the union locals to coordinate the labor of dockworkers and those with similar skill levels that could work on the dock is one measure of this bargaining power. However, both the ILWU and ILA organized workers in other industries, such as fishermen, canneries, and manufacturing near ports. Assuming these workers would strike alongside dockworkers, this definition of bargaining power therefore captures how much hold-up power the union local had in a port county, in terms of how much damage it could do to the overall local economy.

I also include controls for variables that previous work on containerization and technological adoption in general has found to influence adoption timing. $PortShallowness_{c,1953}$ is a categorical variable in five-foot increments with smaller values for deeper ports, as provided by Brooks et al. (2021). This is described in detail in Section 4.2, where it is used to instrument for early container adoption. $LandSupply_{c,1955}$ is an additional geographic cost-shifter used in Ducruet et al. (2024),

[24]Note this is actually run equivalently as a full interaction of a single union density variable and $\mathbf{I}(PacificPort)_c)$.

under the rationale that it is cheaper to expand larger container ports in areas that do not require land reclamation or substantial re-grading. As in Ducruet et al. (2024), it is calculated as the percentage of land cover cells within a 10 kilometer radius of each port categorized in 1955 as sea cells, internal water bodies, wetland or with a terrain gradient above 15%.[25] Since larger ports may be more likely to adopt earlier, I include $\ln(CargoTons)_{c,1953}$, the volume of container-suitable cargo handled by port c in 1953. I also control for $CompetitionContainers_{c,1960}$, the degree of containerized competition faced by port c as of 1960, to account for ports adopting in the face of rivals' adoption (as suggested by e.g. Schmidt-Dengler (2024)).

Finally, I control for other ex-ante port characteristics that, if excluded, may lead to concerns of omitted variable bias for the dockworker union density measures. $OverallUnionDensity_{c,1953}$ is the predicted union density across all industries in county c. I follow Garin and Rothbaum (2022) in calculating this using 1953 estimates of industry union density from Troy (1957) and the industry employment distribution within each county from the 1953 CBP. $ManufacturingEmp_{c,1953}$ is the share of total county c employment in the manufacturing sector in 1953, calculated from the CBP. I also include the other two variables in $InitialConditions_c$ used in the regressions in Section 4.2, the log of a port's 1910 population and its square.

Results from these regressions are included in Table 5. I find a negative and significant value for β_1, the local membership density of the ILA dockworker union, in 1950. The probability of early container adoption is decreasing in union density among Atlantic and Gulf coast ports, where the union fought containerization. On the other hand, I estimate a significant positive value for the β_2 coefficients on ex-ante ILWU local union density. The probability of early container adoption is increasing in union density among Pacific ports where the union cooperated with adoption in exchange for compensation. These results strengthen with additional controls in Column (3), the preferred specification, and even further with an alternative definitions of union density in Column (4) where the density is calculated as union local membership divided by employed population without a BA (rather than without high school). In terms of magnitudes, a port with one standard deviation higher ILA union density on the east coast (15.4%) has a 11.2 percentage point smaller probability of early container adoption. On the Pacific coast, one standard deviation higher ILWU union density (4.2%) is associated with a 12.3 percentage point larger probability of early container adoption. These effect sizes are equivalent to about half of the share of ports that had containerized

[25] This is calculated using data from Sohl et al. (2016) on modeled historical land cover across the US.

Table 5. Linear probability model regressions of port container adoption by 1970

	Non-HS emp density denominator			Non-BA emp denominator
	(1)	(2)	(3)	(4)
% ILA union density, 1950		-0.0042	-0.0073**	-0.0077**
		(0.0026)	(0.0020)	(0.0021)
% ILWU union density, 1950		0.0326***	0.0292***	0.0306***
		(0.0025)	(0.0037)	(0.0039)
Pacific port		-0.2066*	-0.1091	-0.1092
		(0.0860)	(0.0868)	(0.0868)
Port shallowness, 1953	-0.0860***	-0.1033***	-0.0258	-0.0258
	(0.0122)	(0.0182)	(0.0164)	(0.0165)
% Land scarcity, 1955	-0.0013	-0.0015	-0.0012	-0.0012
	(0.0024)	(0.0026)	(0.0027)	(0.0027)
ln(CargoTons), 1953			0.0647***	0.0647***
			(0.0157)	(0.0157)
Competition, 1970			-0.1437*	-0.1438*
			(0.0600)	(0.0600)
% Manufacturing emp., 1950			-0.0076	-0.0076
			(0.0039)	(0.0039)
ln(population), 1910			-0.8719*	-0.8713*
			(0.4227)	(0.4231)
$\ln(\text{population})^2, 1910$			0.0415*	0.0414*
			(0.0195)	(0.0195)
% Overall unionized, 1953			-0.0005	-0.0005
			(0.0032)	(0.0032)
Observations	88	88	84	84

Standard errors clustered by Census Division in parentheses.

* p < 0.10, ** p < 0.05, *** p < 0.01

Notes: Linear regression of indicator that port adopted containers by 1970 on potential predictors. All predictors are measured before containerization begins in 1956 except for the contemporaneous competition from containerized ports (in 1960). ILA density and ILWU density are local longshore union density, calculated as number of union local members as a percentage of potential members, where latter is defined in Columns (1) through (3) as all employed individuals in port with less than-high school education across all industries and in Column (4) as all employed individuals with less than-college education. Pacific port is an indicator that a port is on Pacific coast, controlled by different union (the ILWU) than Atlantic/Gulf coast ports (the ILA). Port shallowness is 8-level categorical variable with smaller values for deeper ports. Land scarcity measures available nearby land to expand a port. ln(CargoTons) is the volume of container-suitable cargo handled by a port. Competition is distance-weighted level of competition faced by workers' county group in 1960 from other ports adopting containers. % Manufacturing employment is the share of county jobs in the manufacturing sector. % All-economy predicted unionized is the expected overall county union density based on its industry employment distribution and national industry unionization rates.

by 1970 on both coasts (21 of 90 ports, or 23%).

These results suggest that the influence of worker bargaining power on adoption is highly dependent on whether these workers are part of a union that has bargained for compensation for their dislocation by the adopted automation. The negative coefficient on bargaining power of ILA union locals is perhaps unsurprising: adoption will occur earlier in ports where the union local is weaker and less able to prevent their displacement. This is in line with views of unions as primarily resisting adoption of technologies that displace their members. However, among ILWU ports where the union bargained to cooperate with adoption in exchange for compensation, there is a positive and significant coefficient on bargaining power. One possibility is that higher unionization rates mean that it is more credible for the union in these ports to uphold its side of the bargain, since a larger share of potential dockworkers are being compensated for their dislocation. Firms are therefore incentivized to innovate to protect their market shares (Beath et al., 1989; Ulph and Ulph, 1994). A complementary interpretation is based on the fact that only more senior ILWU members received compensation, unlike the ILA where more marginal members also were compensated, but all members at much lower amounts–hence the combative stance towards containerization. Adoption therefore appears more likely where there is a greater share of potentially dislocated workers being compensated and at higher amounts. This raises the question of whether there were potential inefficiencies where ports could have compensated workers more (or a larger share of workers) in order to automate earlier, increasing productivity and social welfare.

Results in the other column suggest these adoption patterns follow largely similar relationship as documented in other studies. Column (1) mirrors the first-stage regressions in Brooks et al. (2021) and Ducruet et al. (2024) where adoption is predicted by ex-ante port depth, although unlike in the latter, local land supply does not predict container adoption in this case. This could be due the focus here on explained *early* container adoption specifically or because of a more sample restricted to the US only (rather than globally). A significant positive coefficient on $\ln(CargoTons)_{c,1953}$ in Columns (3) and (4) mirrors results in Koch et al. (2021) where ex-ante higher-output firms are more likely to install industrial robots.

6 Conclusion and future research

This paper analyzes how automation in a tradeable industry impacts workers and how adoption by firms is influenced by union strategies by analyzing the case of US container adoption across

ports and dockworker labour market outcomes. I highlight the importance of indirect channels of job loss from automation in firms that do not adopt the automation, due to business stealing by adopting firms, estimating it is of nearly as large a magnitude as direct job displacement with an adopting firm. In particular I show that ports that adopted containers earlier had better outcomes, as did the dockworkers employed there. I argue that this channel of indirect job loss was taken into account by dockworker unions who attempted to bargain with employers for compensation in exchange for supporting containerization. However, my results in Section 5 suggest that only where a union was able to reach a bargained agreement, and in ports where this bargain was most effective due to higher union density, did this encourage adoption. Otherwise, containerization occurred where non-cooperative unions were less able to resist it.

This contributes to growing bodies of research on the labour market impacts of automation as well as on directed technological change, in particular the role of unions and labour power. The findings suggest in the case of competitive, tradable industries, unions can encourage adoption of even labour-saving technologies. I provide a simple game theory model of competing unions deciding how to approach the threat of automation technological adoption to illustrate which influence their stances. Given that ports where compensation agreements were negotiated appear to experience better outcomes, this appears to be a case where unions and firms can share the rents from a labour-saving technological improvement and therefore both reap the productivity benefits.

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A Appendix

Part

A.1 Iceberg trade costs calculation

Iceberg trade costs $TradeCosts_{cjt}$ are calculated based on the data and methodology in Jaworski and Kitchens (2019). This is based on their matrix of county-to-county travel distance (in miles) and time (in hours) along the interstate, national, and state highway systems network as of 1950, 1960, 1970, 1980, and 1990. I then calculate the monetary cost τ_{cj} of moving between each county pair (a symmetric cost) as the sum

$$\tau_{cjt} = (Distance_{cjt} \times CostPerMile_t) + (TravelTime_{cjt} \times CostPerHour_t)$$

The $CostPerHour_t$ is the hourly wage for truck drivers. The only annual data series available back to 1950 was from a 1981 BLS publication "Union Wages and Benefits: Local Truckdrivers and Helpers, September 3, 1979: Bulletin No. 2089". It provides the hourly wage rate of unionized drivers for 1936-1979 (indexed to 1967=100) as well as average hourly wage rate in 1979 for drivers of $9.61. I append the median hourly wage rate for employed truck drivers (occ1990 code 804) that are union members or covered by union for 1983-1997 from the CPS Outgoing Rotation Group (Ruggles et al., 2022). Values were linearly interpolated for 1978 and 1980-82 since data not available and were re-based to 2005 dollars to match the fuel price data.

Following Jaworski and Kitchens (2019), for $CostPerMile_t$ I calculate the fuel cost per mile in each year as the product of the miles per gallon for Heavy-Duty Trucks from U.S. Energy Information Administration Annual Energy Review [26] and the per gallon Retail Motor Gasoline price from the same EIA publication.[27] Finally, following Jaworski and Kitchens (2019); Hornbeck and Rotemberg (2021); Donaldson and Hornbeck (2016) I convert this county-to-county trade cost τ_{cjt} to an iceberg trade cost between counties by normalizing by the average price per ton of transported goods. I divide τ_{cj} by the average value of a shipment ($854.13 in 2005 dollars, from the US Department of Transportation) then adding one.[28]

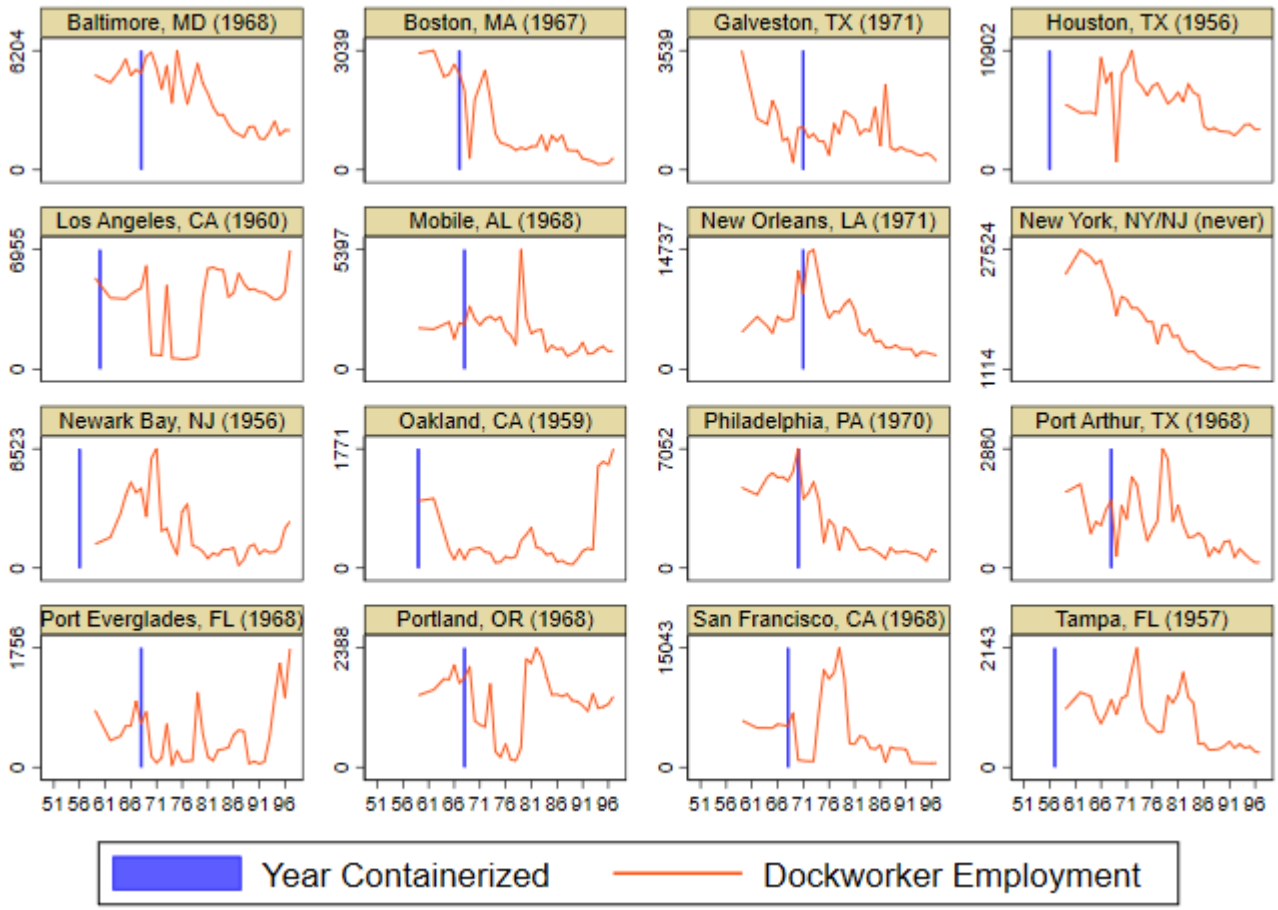
[26] Available at https://www.eia.gov/totalenergy/data/annual/showtext.php?t=ptb0208

[27] Available at https://www.eia.gov/totalenergy/data/annual/showtext.php?t=ptb0524. Leaded was used for 1950-90 and unleaded for 1991-97

[28] I use average value per ton of freight shipment in 2007 of $890 from https://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/10factsfigures/table2_2.htm equal to $854.13(=890/1.042) in 2005 dollars.

A.2 Additional descriptives

Figure A1: Total longshore services employment and container adoption for largest ports



Notes: Dockworker employment is total annual county employment in SIC 4463 "Marine Cargo Handling" from Eckert et al. (2022). Port locations and containerization timing from Brooks et al. (2021).

A.3 OLS cross-sectional regressions

Table A1. OLS Regression of share of US container-suitable cargo handled at port on container adoption

	% of US tonnage			% of US value		
	(1)	(2)	(3)	(4)	(5)	(6)
	1970	1977	1985	1970	1977	1985
Containerized by 1970	0.26	0.21	0.66	0.21	2.35	2.62*
	(0.92)	(1.15)	(0.58)	(0.61)	(1.20)	(1.16)
Competition in end-year	-0.28	-0.38	-0.35	-0.42	0.05	-0.11
	(0.53)	(0.34)	(0.23)	(0.51)	(0.40)	(0.43)
Pre-containerization (1953)	0.48*	0.09	0.17	0.54**	0.16	0.10
	(0.20)	(0.16)	(0.11)	(0.18)	(0.27)	(0.07)
Constant	-12.57	1.50	-1.62	7.01	-7.81	9.82
	(8.78)	(11.30)	(13.35)	(12.84)	(12.87)	(18.44)
Census Division FE	Y	Y	Y	Y	Y	Y
Port controls	Y	Y	Y	Y	Y	Y
Obs.	88	88	88	86	86	86
R-Squared	0.60	0.40	0.48	0.50	0.38	0.34
DV Mean	1.1	1.1	1.1	1.2	1.2	1.2

Notes: OLS regressions of each outcome on an indicator of the port having adopted containers by 1970. Each regression is run on the cross-section of ports without any missing variables and includes the following controls: pre-containerization value of the dependent variable; the level of distance-weighted competition from containerized ports in the end-year; the share of employment in manufacturing in 1950, the log of population in 1910, and the square of the latter; and census division fixed effects. Dependent variables are each port's share of total US container-suitable cargo in terms of tons (Columns 1-3) and value (Columns 4-6) in the listed end-year. Port shipments data from USACE (1953) includes foreign, coastwise, and internal trade at each port in tons by product. Cargo-suitable products are a subset of all products, assessed as of 1968 and reported in El-Sahli (2013). Total cargo value estimated from product values (dollars per ton) of US foreign trade in OECD (2022).

Table A2. OLS regression of % of US total dockworker employment on port container early adoption

	DV: % of total US employment in end-year					
	(1)	(2)	(3)	(4)	(5)	(6)
	1970	1977	1980	1985	1990	1996
Pre-containerization emp	2.07***	1.80***	1.41***	1.05***	0.69**	0.63***
	(0.11)	(0.25)	(0.24)	(0.21)	(0.18)	(0.14)
Containerized by 1970	0.60**	1.12**	1.19***	1.53***	1.79***	1.87***
	(0.20)	(0.28)	(0.24)	(0.35)	(0.37)	(0.39)
Competition in end-year	-0.24	0.14	0.03	-0.15	-0.31	-0.41
	(0.17)	(0.18)	(0.11)	(0.14)	(0.22)	(0.22)
Constant	-0.97	-8.73	-9.49	-8.30	-12.13	-7.50
	(5.53)	(7.96)	(8.91)	(10.80)	(10.10)	(10.91)
Census Division FE	Y	Y	Y	Y	Y	Y
Port controls	Y	Y	Y	Y	Y	Y
Obs.	68	76	76	76	76	76
R-Squared	0.95	0.77	0.81	0.69	0.60	0.52
DV Mean	1.5	1.3	1.3	1.3	1.3	1.3

Notes: OLS regressions of each outcome on an indicator of the port having adopted containers by 1970. Each regression is run on the cross-section of ports without any missing variables and includes the following controls: pre-containerization value of the dependent variable; the level of distance-weighted competition from containerized ports in the end-year; the share of employment in manufacturing in 1950, the log of population in 1910, and the square of the latter; and census division fixed effects. The dependent variable is each port's share of total employment in the Water Transport sector (among sample ports) in the end-year listed. Employment counts are three-year moving averages for smoothing and due to missingness, from Eckert et al. (2020, 2022).