Work Rules in Port Productivity

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Abstract

I show how port productivity changed after a historic labor agreement. In 2008, the International Longshore and Warehouse Union signed a contract agreeing ports on the US West Coast could automate terminals, recognizing there would be job losses. Using a new, ship-level dataset, I study changes in productivity after the signing and after one port automated. Productivity increased about 22% after the new contract. The port that did actually automate was 26% more productive than its peers. I find that the effects persist through the 2015 contract, and suggest possible ways employee-employer relations may alter outside the written contract.

*Email: sam.bailey@usda.gov. The findings and conclusions in this paper are those of the author and should not be construed to represent any official USDA or U.S. Government determination or policy.

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1 Introduction

Union supporters and opponents alike agree their effects go far beyond wages. The work rules governing what workers and employers can and cannot do are often just as contentious as pay, if not more. (Freeman and Medoff, 1984) argue this could benefit productivity, as giving workers a voice offers an alternative to leaving a disappointing firm, preventing costly turnover. However, there is also evidence that these rules may be an inefficient way of splitting rents and their removal can lead to lower prices and more productive firms Schmitz (2005).

This article studies a very particular change in work rules and how the industry's productivity was affected. In 2008, the International Longshore and Warehouse Union (ILWU) agreed to a contract that allowed all ports on the West Coast of the United States to fully automate, even knowing that automated terminals would lead to lower labor demand. Given the union's historical behavior, there is good reason to think employers would not have been able to automate without this provision. Though I am studying a particular contract in a particular industry, the question the provision addresses–what kinds of machinery a firm can invest in, and what happens to workers it may displace–exists across almost all industries and has been a cause of dispute since at least the Industrial Revolution.

The union contract was not the only change during this period: the average ship in my sample grew from a little under 45,000 gross tons to over 60,000, over 33% growth. Larger ships can carry more goods but also take longer to unload. The additional cargo and additional time do not necessarily grow at the same rate. If they do not, then the aggregate productivity (port-wide containers over port-wide inputs) will be biased because it fails to account for changes in inputs. In my data I observe work times for individual ship dockings. Though results with the aggregate and granular data are qualitatively the same direction, I show

that having this fine data is necessary for quantitatively measuring productivity over time.

I measure the impact in two ways. First, I do a simple event study comparing how productively a port can unload a ship before and after after the contract was signed. I observe the labor employed and ship size, so my measure of productivity is a combination of capital and total factor productivity. Allowing for a linear, port-specific time trend, I find there was an average increase in the productivity of unloading of about 22%.

A weakness of the previous approach is there may of course be a time trend unrelated to the contract. Including a linear time trend mitigates the issue but does not eliminate it. Because the union contract (by construction) covers the entire West Coast, I cannot find any nearby ports unaffected. I can, however, study what happens to the port of Los Angeles when it actually built an automated terminal in June 2014. I estimate a difference-in-difference and find that the differential impact of Los Angeles having an automated terminal was about 26% compared to its peer ports. Before automation, Los Angeles actually used slightly more labor than average. After the new terminal was built it used less than average. It is worth noting that the differential effect of automation need not be the same as the coast-wide effect of the new contract, but the fact that both are qualitatively and quantitatively similar is reassuring.

This article follows two major strands of the literature. The first studies how unions and work rules affect productivity. Two articles in particular are closely related to mine. Benjamin Bridgman studies how longshore unions limited productivity growth from containerization (Bridgman, 2018). Even though labor productivity increased, total labor costs fell by much less until much later on. Rather than study how a union reacts to technological change, I am measuring the effects of a change in the work rules themselves. In his study of US and

Canadian iron ore mines, James Schmitz finds productivity increased and prices fell when the mines were exposed to the risk of competition from Brazil (Schmitz, 2005). He concludes that the threat of competition forced firms and unions to redo work rules that had been sharing profits at the cost of efficiency. There are similarities between West Coast ports and US and Canadian iron ore mining. After contract negotiations led to a ten day lockout in 2002, ocean carriers and other logistics firms started to explore alternatives to West Coast ports. Additionally, in 2006 the Panamanian government had announced it would expand the Panama Canal by 2014[1], making the East Coast ports a better substitute. During the 2008 negotiations, there was thus a sense that competition from ports outside the West Coast was higher than it had ever been (Mongelluzzo, 2019).

The second strand studies how measured productivity may differ depending on the level of aggregation. Basu and Fernald (2002) outline a general theory of the differences between measured aggregate productivity and pure technological change. An early empirical article in this literature, Griliches (1963) studies how changes in input quality and economies of scale may bias results. More recently, Oberfield and Raval (2021) show that even when the plant-level elasticity of substitution is constant across time and across firms, the aggregate version of that parameter may change over time due to reallocation. These studies usually emphasize how firm-level production parameters need not be identical to aggregate parameters because of between-firm reallocation. I am saying little about interactions between firms (or ports, in this case) and focusing more on issues of aggregation within a firm. Kehrig and Vincent (2019) have recently shown there can be wide differences in productivity across plants even within the same firm. I show that the aggregate port productivity, while meaningful in its own right, may be very different from that of the physical production

[1]The actual end date was in July 2016.

function we normally treat it as.

2 Background

Automation

In some sense, all US break-bulk ports are automated and have been since the 1970s. The adoption of containers and the mechanized cranes that move them on and off ships eventually led to shipping costs falling almost tenfold and much lower demand for labor (Levinson, 2016). However, when most people in the industry describe a task as "automated," they mean the task requires no human operator. By this definition, the first port automation is generally held to have occurred in Rotterdam, Netherlands, which in 1993 installed container stacking cranes that did not require human operators (Rintanen and Thomas, 2016).

Even ignoring economic considerations, not every job at a port can feasibly be automated with existing technology. The International Transport Forum (ITF) of the OECD breaks container handling up into six activities: lashing, quay crane operation, twist-lock handling, quay to yard transfer, container stacking, and port gate checking. Currently, no port has automated all of these activities, but the ITF claims quay to yard transfer, container stacking, and port gate checking could all be automated and lashing, quay crane operation, and twist-lock handling could not be, given current technology (ITF, 2021). These latter tasks require more manual dexterity and accounting for the slight but unpredictable movements of the ships in the water. In the language of Acemoglu and Autor (2011), these are "non-routine manual tasks," which are among the hardest to automate.

Automation at TraPac

The TraPac Terminal in the Port of Los Angeles uses automated rail mounted gantry cranes (ARMGs) and automated straddle carriers ("Autostrads") (TraPac, 2018). Rail mounted gantry cranes move and stack containers within the container yard. These are rectangular, metal arches usually a little higher than six stacked containers that can straddle 8-10 containers. The crane operates by standing over a container, dropping a container spreader which attaches to the top four corners, lifting, and then moving the container to another part of the yard between the rails the crane is mounted on on. In TraPac, there are also ARMGs that move containers onto trucks and trains. Straddle carriers are a form of what is called "horizontal transport," they move containers from the quay to the container yard. These are smaller and usually not on tracks, but rather have rubber tires (ITF, 2021). Like all ports, TraPac still employs human workers to operate cranes and some of the other machinery, but overall needs fewer. A report from the Los Angeles Harbor Commission predicted even automating just these feature of the terminal would reduce labor demand 40-50 percent (Mongelluzzo, 2015a).

The 2008 Pacific Coast Longshore and Clerks' Agreement

Since it began in the 1930s, the International Longshore and Warehouse Union (ILWU) has been one of the most powerful labor unions in the United States. It has been able to guarantee high wages for its workers[2], but in this article I focus on its jurisdiction over what investments are allowed in its work spaces. Part of the union's success comes from its measured approach to new technology. At what was probably its moment of greatest strength in the late 1950s and

[2]The actual average pay of an ILWU member is a contentious topic. The Pacific Maritime Association (PMA), the employers' group that does payroll, says the average longshore union member received $194,350. However, this does not include casual workers or workers who do not work full-time.

early 1960s, the union did not oppose mechanization but rather bargained such that existing members would continue to receive benefits and pensions even as the demand for their labor decreased. Indeed, ILWU president Harry Bridges even argued there should be *compulsory* mechanization, arguing "we are less interested in getting more men than we are in getting machines to make the work easier" (Joint Meeting, August 7, 1963, p. 11, quoted in Hartman (1969)). (The fact that port labor costs did not fall is the main reason Bridgman (2018) argues containerization did not lower trade costs until years after it began.) It has continued that tradition more recently. In the 2008 contract, the ILWU agreed to include the following paragraph:

> **1.72** It is recognized that the introduction of new technologies, including fully mechanized and robotic-operated marine terminals, necessarily displaces traditional longshore work and workers, including the operating, maintenance and repair, and associated cleaning of stevedore cargo handling equipment. The parties recognize robotics and other technologies will replace a certain number of equipment operators and other traditional longshore classifications. It is agreed that the jurisdiction of the ILWU shall apply to the maintenance and repair of all present and forthcoming stevedore cargo handling equipment in accordance with Sections 1.7 and 1.71 and shall constitute the functional equivalent of such traditional ILWU work. [...]

For the first time, the contract explicitly allowed full automation on terminals. Not only was automation allowed in principle, but the union acknowledged that automation could go on even if it was known to cost union jobs. This provision was not snuck in by PMA or union leadership; it was well understood by union rank-and-file. A special issue of the union newsletter *The Dispatcher*

included it and other major changes in a special August 2008 issue (Merrilees, 2008a). Not only was it understood, the 2008 contract was overwhelmingly supported: over 75% of the voting members in the Longshore Division supported it (Merrilees, 2008b).

Jurisdiction

Why would the ILWU allow automation it believed would reduce demand for labor? A letter of understanding from ILWU president Robert McEllrath to PMA president James McKenna (reprinted in the same August *Dispatcher* issue) goes into more detail:

> During the course of the 2008 PCL&CA [Pacific Coast Longshore and Clerks' Agreement] negotiations, the Parties discussed the assignment of maintenance and repair work to the ILWU coastwide bargaining unit to offset the introduction of new technologies and robotics that will necessarily displace/erode traditional longshore work and workers. The scope of ILWU work shall include the pre-commission installation per each Employer's past practice (e.g., OCR, GPS, MODAT, and related equipment, etc., excluding operating system, servers, and terminal infrastructure, etc.), post-commission installation, reinstallation, removal, maintenance and repair, and associated cleaning of all present and forthcoming technological equipment related to the operation of stevedore cargo handling equipment and its electronic in all West Coast ports except for those, and only those, specific marine terminal facilities listed as "red-circled" below [...] (Merrilees, 2008a)

In an April 2022 retrospective of the 2002 contract negotiations over computerizing some of the clerks' tasks, the *Dispatcher* says "The ILWU's position

in technology in 2002 was the same as it was 42 years prior. In the 1960 Mechanization and Modernization agreement negotiated by Harry Bridges, the union embraced technological changes and, in return, the contract recognized that all jobs created by the new technology would be ILWU jurisdiction." Indeed, when the union did begin to push back on containerization at the end of the 1960s, the point of contention was not over mechanization but over non-ILWU workers packing and unpacking the containers in warehouses (Hartman, 1969). It was a dispute over jurisdiction, not technology per se. In the 2008 contract, the ILWU received what it thought was a guaranteed jurisdiction over new positions, on top of the increased pension and wages. When that jurisdiction seemed less certain several years later, its position changed (Mongelluzzo, 2023).

Was the Automation Clause Binding?

A written contract is one thing, whether it makes a difference in behavior is another. Port terminals may have had no intention to ever automate terminals. Conversely, the ILWU may have never had any intention of opposing automation if it had not been explicitly allowed. These possibilities seem unlikely. The first is the most obviously false: port terminals did automate. They used technology that was known in 2008 and that other ports had already implemented. The second, that even without this provision, the union would not have opposed automation, also seems wrong for a similar reason. Even with the provision in place, the ILWU has vocally opposed automation as it has happened. As soon as TraPac began automating some tasks, workers responded by "hard-timing" or working slower than normal (Mongelluzzo, 2014a). In 2020, ILWU president Willie Adams urged California governor Gavin Newsom oppose automation there (Tirschwell, 2020) . In Washington State, the union has fought against state grants for replacing existing machine with low-emission ones that also use less labor (Editorial, 2021). What the union has *not* done is stage

strikes or otherwise disrupt work on the docks, which would be a violation of the terms. There is therefore good reason to assume employers and employees take the contract as binding.

The contract for the period at the end of the data is not the 2008 contract; it was one signed in 2015. The 2015 contract did not make as many sweeping changes and it kept the paragraph on automation. Automation was also not yet a major point of contention: union negotiators were more upset with jurisdiction over chassis maintenance and repair (Mongelluzzo, 2015b). It is important to consider, though, because even if the contract itself was unremarkable, the negotiations were far more aggressive than in 2008, culminating in a work slowdown in early 2015. Figure 1 shows the total number of vessels coming to the West Coast. The effects of the slowdown are visible in the 200 fewer vessels appearing than there otherwise would have been. When I'm studying the effects of these contracts the written clauses are important, but so, too, are the signals each party may give in how it plans to operate for the coming years.

3 Data

Table 1 lists the data sources I use. The dispatch summaries from the Pacific Maritime Association (PMA) are the most important as these contain fifteen years (2005-2020) of labor data for four ports on the West Coast of the United States: Seattle, Tacoma, Oakland, and Los Angeles/Long Beach. (Los Angeles and Long Beach are actually two separate ports, but they are close enough to draw on the same pool of labor.) I match the dispatch summaries with data from www.vesseltracking.net for vessel sizes. I also match the vessel sizes to bill of ladings from 2007-2015, in order to measure the relationship between ship size and quantity unloaded.[3] I would ideally match the dispatch summaries

[3]Bills of lading are more or less receipts for transporting goods by ship. I use data originally prepared for Holmes and Singer (2018) and thank Tom Holmes and Ethan Singer for sharing

with the bills of lading, but differences in how the two datasets record when a vessel enters a port makes the matching very noisy in a non-random way.

Source	Variables
PMA dispatch summaries	vessel hours at port, total hours worked per vessel, total gangs employed per vessel
PMA annual reports	aggregate hours, aggregate tonnage
www.vesseltracking.net	vessel sizes
Bills of lading	containers unloaded per vessel

Table 1: Data Sources

In Table 2, I list summary statistics for some of the main variables. My main measure of interest will typically be containers per gang-hour conditioned on vessel size. I do not observe the relationship directly, but I am able to observe the relationship between containers and size and between gang-hours and size, and from these I can indirectly measure the relationship between containers and gang-hours.

	Mean	Standard deviation	Min	Max	Obs
Total gangs	9.67	10.7	1	132	102,564
Total work hours	24.5	20.7	5	513	102,609
Total gang-hours	408	806	5	47,520	102,564
Total hours	45.2	81.4	5	8,789	102,609
Length (m)	260	79.6	6.18	477	45,772
Containers unloaded	362	1,157	1	15,287	41,239

Table 2: Summary Statistics

Not visible in the table but important for my story are time trends taking place during this time. Figure 1 shows the total number of vessels docking each month on one of the four ports in the sample. There are many fluctuations, from business cycles, seasonality, and idiosyncratic reasons (like the 2015 work slowdown), and overall there is a slight decrease in total visits, in part due to traffic lost to the East Coast. A very different graph is Figure 2, which shows the

their data.

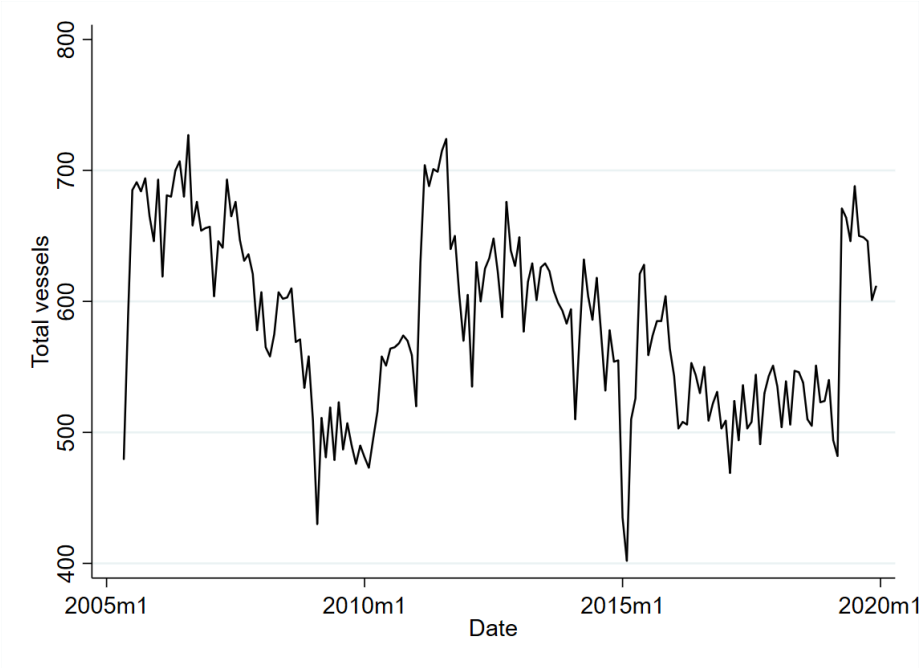


Figure 1: Vessels Docking at West Coast

average ship length over the same period. Here there is a clear trend upward of 10-15%. The scale economies from larger vessels have a major impact on productivity, and failure to consider these changes in the inputs for the ports will bias any productivity measures.

To my knowledge, the dispatch summaries have not been used in any prior research. Gathering and preparing them in a usable form is a contribution of this article, so I will briefly describe their construction.

The dispatch summary includes the name of the vessel, how many new gangs to work it, how many gangs are returning, the date and time of the shift, and the date and time of the vessel's arrival. Figure 3 shows what each page looks like. Summaries go back to the end of 2004 and up to the present. I limit the sample to spring of 2005 to the end of 2019 because of spotty observations early on and to avoid any impact of the COVID-19 pandemic.

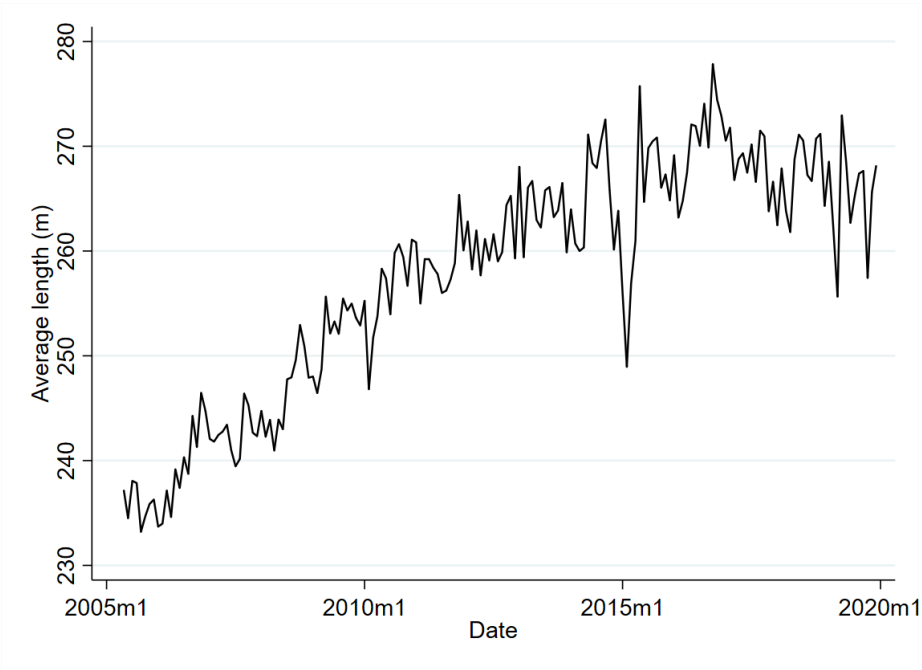
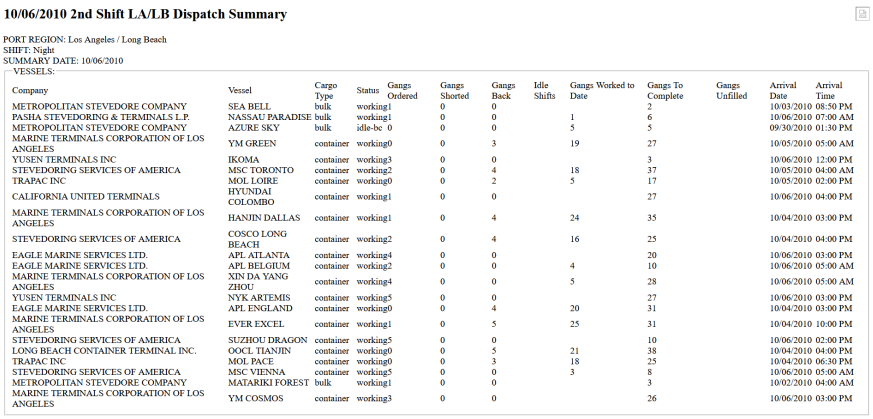


Figure 2: Average Vessel Length

The unit of observation is a stop at a port with at least one hour of work requested, what I call an "unloading." (Some vessels show up for only a few shifts and are idle the whole time. I drop these from the sample.) I identify an unloading by the combination of vessel name, port, and arrival date. When a vessel no longer appears in the summary dispatches, I assume it has left the port. The "total hours in port" are the sum of the shifts the vessel appears in. The "total hours working" are the sum of the shifts where the status is listed as "working." (In Figure 3, all the vessels in this shift were being worked on except for the *Azure Sky*, which was idle.) The "total gangs" is the running total `Gangs Worked to Date` in the last shift of the stop. Sometimes this column is blank, in which case I use `Gangs To Complete`. Finally, the "gang-hours" are the product of the total number of gangs and the total number of hours of work.

The summaries list the total number of "gangs" requested. The number

of workers on each gang is not listed. If the number or types of workers on a gang were flexible or changing over time, that would bias labor productivity. However, that does not appear to be the case. Contract rules are clear about what kinds of workers compose a gang and how many of them there are, and these rules do not change over time. It is of course possible that as technology changes, these workers are not performing the same tasks. I do not take a stand on whether these particular rules are efficient or not.



10/06/2010 2nd Shift LA/LB Dispatch Summary

PORT REGION: Los Angeles / Long Beach
SHIFT: Night
SUMMARY DATE: 10/06/2010

VESSELS:

Company	Vessel	Cargo Type	Status	Gangs Ordered	Gangs Shorted	Gangs Back	Idle Shifts	Gangs Worked to Date	Gangs To Complete	Gangs Unfilled	Arrival Date	Arrival Time
METROPOLITAN STEVEDORE COMPANY	SEA BELL	bulk	working	1	0	0			2		10/03/2010	08:50 PM
PASHA STEVEDORING & TERMINALS L.P.	NASSAU PARADISE	bulk	working	1	0	0		1	6		10/06/2010	07:00 AM
METROPOLITAN STEVEDORE COMPANY	AZURE SKY	bulk	idle-bc	0	0	0		5	5		09/30/2010	01:30 PM
MARINE TERMINALS CORPORATION OF LOS ANGELES	YM GREEN	container	working	0	0	3		19	27		10/05/2010	05:00 AM
YUSEN TERMINALS INC	IKOMA	container	working	3	0	0			3		10/06/2010	12:00 PM
STEVEDORING SERVICES OF AMERICA	MSC TORONTO	container	working	2	0	4		18	37		10/05/2010	04:00 AM
TRAPAC INC	MOL LOIRE	container	working	0	0	2		5	17		10/05/2010	02:00 PM
CALIFORNIA UNITED TERMINALS	HYUNDAI COLOMBO	container	working	1	0	0			27		10/06/2010	04:00 PM
MARINE TERMINALS CORPORATION OF LOS ANGELES	HANJIN DALLAS	container	working	1	0	4		24	35		10/04/2010	03:00 PM
STEVEDORING SERVICES OF AMERICA	COSCO LONG BEACH	container	working	2	0	4		16	25		10/04/2010	04:00 PM
EAGLE MARINE SERVICES LTD.	APL ATLANTA	container	working	4	0	0			20		10/06/2010	03:00 PM
EAGLE MARINE SERVICES LTD.	APL BELGIUM	container	working	2	0	0		4	10		10/06/2010	05:00 AM
MARINE TERMINALS CORPORATION OF LOS ANGELES	XIN DA YANG ZHOU	container	working	4	0	0		5	28		10/06/2010	05:00 AM
YUSEN TERMINALS INC	NYK ARTEMIS	container	working	5	0	0			27		10/06/2010	03:00 PM
EAGLE MARINE SERVICES LTD.	APL ENGLAND	container	working	0	0	4		20	31		10/04/2010	03:00 PM
MARINE TERMINALS CORPORATION OF LOS ANGELES	EVER EXCEL	container	working	1	0	5		25	31		10/04/2010	10:00 PM
STEVEDORING SERVICES OF AMERICA	SUZHOU DRAGON	container	working	5	0	0			10		10/06/2010	02:00 PM
LONG BEACH CONTAINER TERMINAL INC.	OOCL TIANJIN	container	working	0	0	5		21	38		10/04/2010	04:00 PM
TRAPAC INC	MOL PACE	container	working	0	0	3		18	25		10/04/2010	06:30 PM
STEVEDORING SERVICES OF AMERICA	MSC VIENNA	container	working	5	0	0		3	8		10/06/2010	05:00 AM
METROPOLITAN STEVEDORE COMPANY	MATARIKI FOREST	bulk	working	1	0	0			3		10/02/2010	04:00 AM
MARINE TERMINALS CORPORATION OF LOS ANGELES	YM COSMOS	container	working	3	0	0			26		10/06/2010	03:00 PM

Figure 3: Screenshot of a dispatch summary

4 Model

I build a simple production function as a framework for understanding productivity, changes to it, and how aggregation could affect its measurement.

Production function

I use a Cobb-Douglas production function similar to Cullinane and Song (2006). Inputs are labor, port infrastructure, and ships, and outputs are containers unloaded from the ship. This is not identical to "containers leaving the port" as there are several steps between when a container is placed on the berth and

when it is put on the train or truck or other ship. However, unloading the ship is usually constrained by the space on the berth available, which depends on the efficiency of yardside and berth-to-yard activities (Mongelluzzo, 2014b). The total amount of goods a ship unloads is a function of the size of the ship and the port where it is unloading.

The main unit of analysis is a ship unloading at a port. For unloading i at port p in month-year t,

$$Q_{it} = L_{it}^{\alpha} K_{it}^{\sigma_{pt}} S_{it}^{\gamma} e^{\omega_{pt} + \nu_{it}} \tag{1}$$

where L_{it} is labor, K_{it} is capital/infrastructure, S_{it} is the size of the ship, Q_{it} is the number of containers unloaded, ω_{pt} is a port-level productivity term observed by the ports but not the econometrician, and ν_{it} is a random productivity shock unobserved by everyone. All of these are per unit time the ship is in port; e.g., Q_{it} is the number of containers unloaded per hour it is in port, L_{it} is the number of gang-hours working per hour it is in port, etc.[4]

Labor and capital enter the production function in a typical way, except that the scale elasticity of capital, σ_{pt}, can vary over ports and over time. As Acemoglu and Restrepo (2018a) show, Cobb-Douglas with fixed elasticities cannot explain declining labor demand in response to changes in factor productivity. Even more general factor-augmenting models like constant elasticity of substitution are unable to do so for realistic parameter values. In Acemoglu and Restrepo (2018b), they describe a "task-based" model that explicitly allow for capital to substitute for labor in certain tasks. They show that the overall

[4] As written, this production function allows for an arbitrarily large number of containers to be unloaded from a ship of size S_{it} as long as L_{it} and K_{it} are large enough. The port cannot of course actually do this, no amount of labor can unload more containers than exist. A more accurate function would be $Q_{it} = \min\{L_{it}^{\alpha} K_{it}^{\sigma} S_{it}^{\gamma} e^{\omega_{pt} + \nu_{it}}, S_{it}\}$, where the number of containers unloaded is bounded by the number of containers that can fit on the ship. In practice, no ship is ever entirely unloaded in an hour or less so this bound is not meaningful for the estimation.

production function can take a Cobb-Douglas form with scale elasticities that change as the automation frontier moves.

Ship size is included because of the scale economies from larger ships. If there are fixed costs of unloading any ship, a larger one may be unloaded faster than two smaller vessels carrying the same quantity. There may also be diseconomies, if any berth can take a small ship but only a select number can take larger ones. Past work by the *Journal of Commerce* found that at least for very large ports, containers can be unloaded from larger ships faster than small ones (JOC, 2013).[5]

Equation (1) is very general but not all the parameters are identified with the data I have. I assume that the same level of capital is available for all unloadings at the same port at the same time, so for all i at port p, $K_{it} = K_{pt}$, and in practice treat $K_{it}^{\sigma_{pt}} e^{\omega_{pt}}$ as a single term, G_{pt}. In logs the function is thus

$$q_{it} = \alpha \ell_{it} + \gamma s_{it} + g_{pt} + \nu_{it} \tag{2}$$

Effects of new contract

The new contract affects production through a combination of new capital k_{pt}, changes in capital share σ_{pt} and port-wide productivity ω_{pt}. These changes would show up as level shifts through the g_{pt} term. After a new contract at time t, the port level productivity g_{pt} becomes $g_{pt} + c_t$. This c_t is the effect of the contract, not necessarily automation itself. In the case where I do observe a terminal becoming fully automated, I allow that to have a different effect.

[5] For example, in 2012 the Qingdao Qianwan Container Terminal could unload 90 containers per hour from vessels under 8,000 TEU but 136 containers per hour from vessels over 8,000 TEU (JOC, 2013).

Direct effects of automation

There may be productivity effects from automation directly. For a port that automates, I say the additional productivity effect is a_{pt}. Thus, the expanded production function is

$$q_{it} = \alpha \ell_{it} + \gamma s_{it} + g_{pt} + c_t + a_{pt} + \nu_{it}$$

Aggregate versus average productivity

"Aggregate" productivity is defined as the ratio of coast-wide output over coast-wide inputs. "Average" productivity is the average of the ratios of unloading-level output over unloading-level inputs. Neither measure is more "correct" than the other but their usefulness depends on the question being asked. (See Basu and Fernald (2002) for examples of how aggregate may be useful even when it does not reflect technological change.) I am interested in a change in technology, broadly defined, rather than between-port reallocation or changes in inputs, and therefore need to measure average. Because of scale economies and changes in inputs, these values may not be the same.

A simple decomposition shows the relationships between the two. For simplicity I here show labor productivity, but the same results would hold for total factor productivity if the labor term were replaced with a weighted geometric mean of all inputs. For each unloading i, Q_i is the quantity unloaded and L_i is the labor employed. The labor productivity of unloading i is $A_i \equiv \frac{Q_i}{L_i}$. Let $\mathcal{A}$ be the aggregate labor productivity, i.e.,

$$\mathcal{A} \equiv \frac{Q}{L} \equiv \frac{\sum_i Q_i}{\sum_i L_i}$$

Rearranging, we get

$$\frac{\sum_i Q_i}{\sum_i L_i} = \frac{\sum_i \frac{Q_i}{L_i} \times L_i}{\sum_i L_i} = \frac{\sum_i A_i \times L_i}{\sum_i L_i} = \frac{\mathbb{E}[A_i L_i]}{\mathbb{E}[L_i]} = \frac{Cov(A_i, L_i)}{\mathbb{E}[L_i]} + \mathbb{E}[A_i]$$
$$\Rightarrow \mathcal{A} = \mathbb{E}[A_i]\Big(corr(A_i, L_i) + 1\Big)$$

If the unloadings with higher labor productivity A are correlated with more labor employed, the measured aggregate productivity $\mathcal{A}$ will be higher than the average A. If higher labor productivity is correlated with less labor, the opposite will be true. Returning to the parameterized production function: holding all else equal, if there are decreasing returns for labor ($\alpha < 1$) we would expect to see unloadings with more labor to have lower productivity: $corr(A_i, L_i)$ is negative, and $\mathcal{A} < \mathbb{E}[A_i]$. If there are increasing returns, we would expect to see the opposite, $\mathcal{A} > \mathbb{E}[A_i]$.

I am interested in changes in productivity. If there were only a level difference between $\mathcal{A}$ and $\mathbb{E}[A_i]$ that was constant over time, looking at $\mathcal{A}$ would be sufficient. However, labor is not the only input. Ships sizes are changing during this period, which means $corr(A_i, L_i)$ is also changing over time. To accurately measure the average productivity, I need unloading-level data.

5 Estimation

Each observation is at the level of unloading. For each estimation, I also run a version with aggregated data at the port level. These versions are identical to the estimations at the level of unloading except for fixed effects that cannot be identified at more aggregated levels.

Constructing output

To construct this output measure for each unloading I need to know the amount unloaded and how long the vessel was sitting at port. I only observe how many containers actually came off of a ship for a smaller dataset that does not include the other inputs. I therefore regress

$$\log\left(\text{totalcontainer}\right)_{it} = \eta_s s_{it} + PortFE_s + \varepsilon_{s,it} \tag{3}$$

directly on the smaller sample and use this to predict the total number of containers for all unloadings. The left-hand side is here *not* q_{it}, which is a flow variable that depends on how long the vessel is sitting at port: $\hat{q}_{it} = \frac{\text{predicted total containers}}{\text{hours at port}}$ Note that the fixed effect here does not vary with time. This is a limitation of this particular sample, which displays plenty of cross-sectional variation but only for a limited number of years. Another limitation is that because the numerator of q_{it} is predicted from ship size s_{it}, the only variation in future regressions is coming from the time at port.

Effects of contracts

I am interested in the effects c_y of the new contracts. Because the contract effect is the same for any port to which it applies, I would ideally see some ports affected and some unaffected. If productivity trends were the same for all ports, I could measure c_y simply by comparing the differences across ports. However, the contracts are coast-wide, and I therefore need to make additional assumptions.

First, I assume that outside of the effect of the contracts, growth in g_{pt} is constant, $g_{pt} = constant_p + r_p t$. Including a time trend then accounts for these additional effects.

I estimate the regression

$$\hat{q}_{it} = \beta_\ell \ell_{it} + \beta_s s_{it} + \sum_c \mathbb{1}_{\{t \in c\}} \beta_c + \sum_p \mathbb{1}_{\{port=p\}} \Big(\delta_p + r_p \times t \Big) + \varepsilon_{it} \quad (4)$$

This is the empirical counterpart to equation (2) with the effects of the contracts. Output $\hat{q}_{it}$ is created as described above, ship size s_{it} is the logged length in meters, and labor ℓ_{it} is the total number of gangs per hour at dock. The parameters β_c identify the effects of contracts c_y. β_ℓ is an estimate of α and β_s is an estimate of γ.

There are good reasons to be unsatisfied with only a time trend. First, it is unlikely productivity growth is constant over time, and it is not difficult to think of patterns in the data that could lead to inaccurate estimates. Suppose productivity is roughly constant until a plunge near the end of the period. The time trend would be negative, and the estimated contract effects would be inflated. On the other hand, suppose that all changes in productivity are due to the new contracts, that there is otherwise no other trend. Some of that growth will be attributed to the linear trend, and so I will actually underestimate the effects of the contract.

Direct effects of automation

I cannot fully address the issues just described because I do not observe a group of ports unaffected by the contracts. However, even though all ports were *allowed* to automate after 2008, only a few terminals actually did. I can, then, compare ports that automated to those that did not while holding fixed any coast-wide time effect. I regress the following

$$\hat{q}_{it} = \beta_{\ell,auto}\ell_{it} + \beta_{s,auto}s_{it} + \mathbb{1}_{\{it\in auto\}}\beta_{auto} + \sum_{p,t}\mathbb{1}_{\{port=p,time=t\}}\delta_{pt} + \varepsilon_{it} \quad (5)$$

Here, rather than a linear time trend, there are separate port-month fixed effects allowed to vary flexibly. The indicator $\mathbb{1}_{\{it\in auto\}}$ is positive only for ports with a terminal that automated. The most important incident of automation in these data was the TraPac Terminal in the Port of Los Angeles. It started using automated cranes in the container yard and automated straddle carriers to move containers from berth to container yard starting in summer 2014. In 2016, the Long Beach Container Terminal at the Port of Long Beach completed one of a planned three steps towards automation. I could include a second dummy for that terminal's automation, but because the data do not distinguish between Los Angeles and Long Beach, it would be collinear with the first dummy.[6]

I should emphasize here that (5) is not a better version of (4). The equations are measuring different effects. It is possible that even among ports that did not build fully automated terminals, the new terms led to changes in productivity. Perhaps terminal operators were more likely to make technical investments short of fully automation, being less uncertain about potential union responses. Workers may also have behaved differently, knowing future automation was a real possibility. As often happens, there is one effect that I am most interested in knowing and which is hard to reliably estimate. There is another which is easier to accurately estimate and is of less interest. In this article I report both.

[6]The port authorities of Los Angeles and Long Beach are distinct organizations with separate governing bodies, but the ILWU locals and union halls are the same for both.

6 Results

Output

Table 3 shows the relationship between quantity unloaded and length. The left-most column of each table includes the fixed effects described in the Estimation section. In the next column, I aggregate up to the port level and perform similar regressions. I say "similar" because more aggregated versions are not necessarily identified with port-time or even port-level fixed effects.

	Unloading	Port
η_s	2.00***	0.0780
	(0.544)	(0.0269)
Fixed Effects?	Y	Y
N	31,675	72

Table 3: Containers unloaded as function of ship length
*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$. Fixed effects are at port level. Standard errors are clustered at the port level.

The quantity unloaded roughly increases with the square of the length of the ship. This makes sense: if quantity moves one-to-one with volume and ships differed only by length, a ship twice as long would hold twice as much and we would expect a linear relationship between length and quantity. If a twice as long ships was also twice as wide and had a draft twice as high, we would expect a cubic relationship. The reality is likely somewhere in between, which is what I estimate.

Aggregation

In Figure 4 I plot the containers per gang using the coast-wide aggregate labor productivity and the productivity of the average unloading. This shows levels of labor productivity, rather than the changes in TFP and capital I am estimating in the regressions, but already it is clear that 1) aggregate and average

persistently differ and 2) the amount by which they differ varies over time.

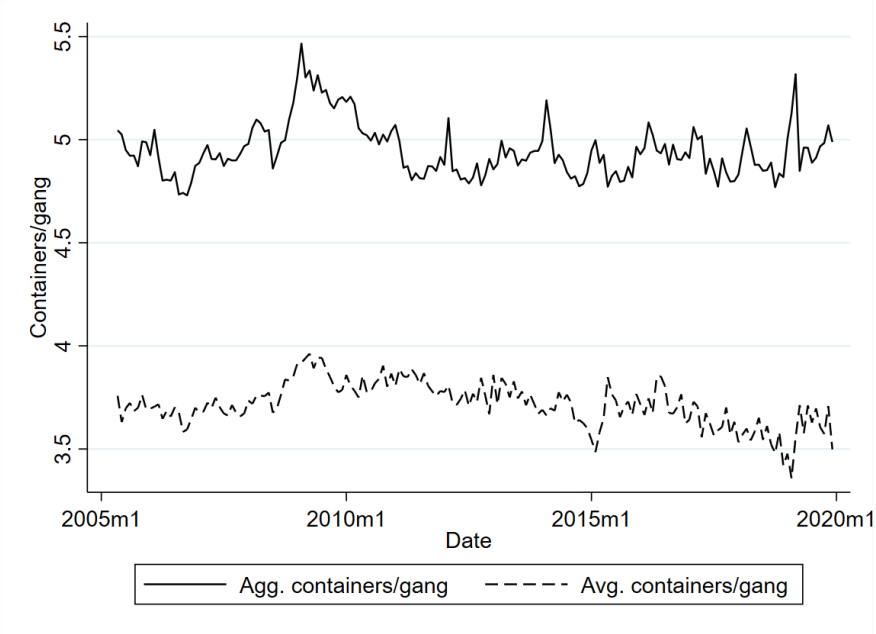


Figure 4: Coast-wide versus average unloading productivity

Aggregation has large effects on the estimated parameters.[7] In Table 3, an estimation even at the level of port-month produces a much lower elasticity not significantly different from zero. This result could occur if the total number of containers demanded at a single port is relatively inelastic. In that case, smaller vessels would unload a little more than average for them and larger ones would unload a little less, and variation in the total length would appear unconnected with total unloaded, even as we know, on average, larger vessels must be unloading more. Thus, observations even at the firm level may return misleading production parameters.

[7]The variables used here are the logged total number of containers, logged total gang-hours, and logged sum of the lengths of all unloadings. If I use logged mean lengths I get similar results.

Effects of contracts

Column 1 of Table 4 shows the main results of the contracts. Removing the trend, after the 2008-2015 contract was signed, productivity increased by 22%. The level for the 2015-2019 contract is slightly higher but the difference is not significant (in a t-test, $\chi^2 = 0.59$). If I restrict the sample to the months before TraPac Terminal was automated, the number is lower but not by much (around 17%) and still significantly positive.

What explains this growth? Part of it is likely the automation itself, and in the next section I provide evidence that the port that automated did experience higher productivity than the others. Another reason may be that even in ports that did not automate, the ILWU lost jurisdiction over tasks it previously monopolized. During this period, carriers sold off their chassis to independent firms they started leasing from. The ILWU had fought for jurisdiction on maintenance and repair for the new automated systems, but it did not have jurisdiction over the maintenance and repair of these chassis owned by outside firms (Mongelluzzo, 2015b). Jurisdiction over maintenance and repair of new machinery may also have been less sizeable than initially realized, as newer machines require less maintenance (Mongelluzzo, 2014a).

It is unlikely this can all be explained by the ILWU being caught unaware, though. These maintenance and repair rules were not changed in 2015, even after their effects were clear (Mongelluzzo, 2015a). More likely, the concessions made reflected the changing competitive environment of West Coast ports. Bridgman (2015) provides a model of why when the industry is faced with greater competition, a union may be willing to reduce work rules. Rules often serve as a way to move more of the firm's surplus to workers without necessarily increasing the marginal cost of labor (which would lower employment, all else equal). As the surplus decreases, such rules become less important. During the

period I am studying, ports on the West Coast were losing business to East Coast ports that were investing in deeper harbors and which, after the Panama Canal expanded in 2016, were more accessible to larger ships from East Asia (Bailey, 2021), (Mongelluzzo, 2019).

Table 4 also shows results for port aggregations. As with the earlier regressions, the estimated effect of the contracts are different from the unloading, albeit non-significantly. More different is the estimate for labor, and the sign of the effect of ship size flips [8]. The granular results for both regressions may be biased downwards if there is measurement error in the independent variables. In Appendix A I discuss where this error may occur and how it compares to the aggregation bias.

At this point I should emphasize again that the regressions in the second column of Table 4 are not wrong or meaningless. The port-level labor productivity is a well-defined object. However, as I am studying the effect on the technology, on the process of unloading itself, these are not the numbers I am interested in.

At level of...	Granular (Unloading)	Aggregate (Port)
β_ℓ	0.500***	1.03***
	(0.0152)	(0.0673))
β_s	1.37***	-0.575***
	(0.193)	(0.135)
$\beta_{2008-2015}$	0.217***	0.286***
	(0.0288)	(0.0209)
$\beta_{2015-2019}$	0.256***	0.403***
	(0.0242)	(0.0643)
N	62,073	456

Table 4: Contract effects on logged containers per hour
*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$. Not shown: Time trend and port fixed effects. Standard errors are clustered at the port level.

[8] The port-level "ship size" is again the log of the sum of all the ships' lengths. Thus, a port visited by fifty 200 meter vessels would have the same aggregate length as one visited by twenty-five 400 meter ones.

Effects of automation

Table 5 shows the results of the difference-in-difference with the TraPac Terminal becoming automated in June 2014. The productivity increased by around 26% compared to the other ports at the same time. This does not mean the total productivity growth of Los Angeles was 22% plus 26%, as the average 22% increase over all the ports includes the increase due to automation at Los Angeles.

	Granular (Unloading)	Aggregate (Port)
β_{auto}	0.258***	0.0762
	(0.0534)	(0.0486)
Port FE?	Y	Y
Time FE?	Y	Y
N	62,073	456

Table 5: TraPac Terminal automation difference-in-difference
*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$. Standard errors are clustered at the port level.

7 Conclusion

Far beyond just determining pay or labor supplied, unions can determine the technology of production itself. In this article, I have shown how an unprecedented change in the ILWU contract was followed by a productivity increase of 22%. Because the data I use are at the level of unloading a ship, I can comfortably consider this a change in the "physical" productivity of the unloading process, rather than reallocation within a port.

Part of this increase was surely the automation itself, but there was also growth before any of the terminals were actually automated. Increased competition from East Coast ports may have played a role in the union making more concessions, both explicitly (as in the clause allowing automation) and implicitly (as in the decision to ultimately not require chassis maintenance and repair

in the 2015 contract). To understand productivity changes, it is beneficial to understand the context in which that adoption was allowed or prevented from happening.

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A Appendix

Aggregation bias or measurement error?

If observations are measured with error, the granular regressions will be biased towards zero and may be no more reliable than the aggregated regressions. In fact, for classical measurement error, aggregating by groups may lead to more consistent results ((Pakes, 1983)).[9]

There are two potentially important sources of measurement error in the data I use. First, I observe hours at the level of a shift. If a ship is present and being worked on at the beginning of a shift, I do not observe if it stays the whole shift, leaves halfway through, or leaves one hour after the shift starts. A second source of error are worker types. There is a rigid seniority list in who is called up for work. In periods of less work, the only people called will be senior union

[9] I thank Amil Petrin for pointing this out.

members, who have longer tenure and more experience. When there is more work the employers may call up people from the casuals roll, who have much less experience. I treat these workers as identical, potentially erasing important differences in productivity.

I cannot completely discount the possibility of measurement error, but can at least provide evidence aggregation error is also an issue. Arthur Lewbel has shown that for log-linear models, a sufficient and necessary condition for aggregated regressions to return the same parameters as granular regressions is that the distribution of the right-hand side variables are "mean scaled" ((Lewbel, 1992)). In other words, if ship lengths are x_{ipt} and the mean ship length at each port-year-month level is X_{pt}, then the distribution of a variable $z_{ipt} \equiv \frac{x_{ipt}}{X_{pt}}$ should be independent of X_{pt}.[10]

In Figure 5, I show the relationship between the mean vessel size and another moment of its distribution, standard deviation. Clearly, the distribution of size is not independent of the mean size. Port-year-months with larger vessels on average also have less dispersion. Unfortunately it is difficult to say the direction of the bias without knowing the value of the true parameter, but in the case of log normally distributed variables the magnitude increases in proportion to the covariance between $logX_{pt}$ and standard deviation. The granular results would therefore at the very least be a lower bound on the true parameter. In cases where they exceed the aggregated parameters, we can therefore take them to be closer to the truth.

[10] An intuitive example from Lewbel is personal income. Personal income is mean scaled if the Gini coefficient does not change with mean income.

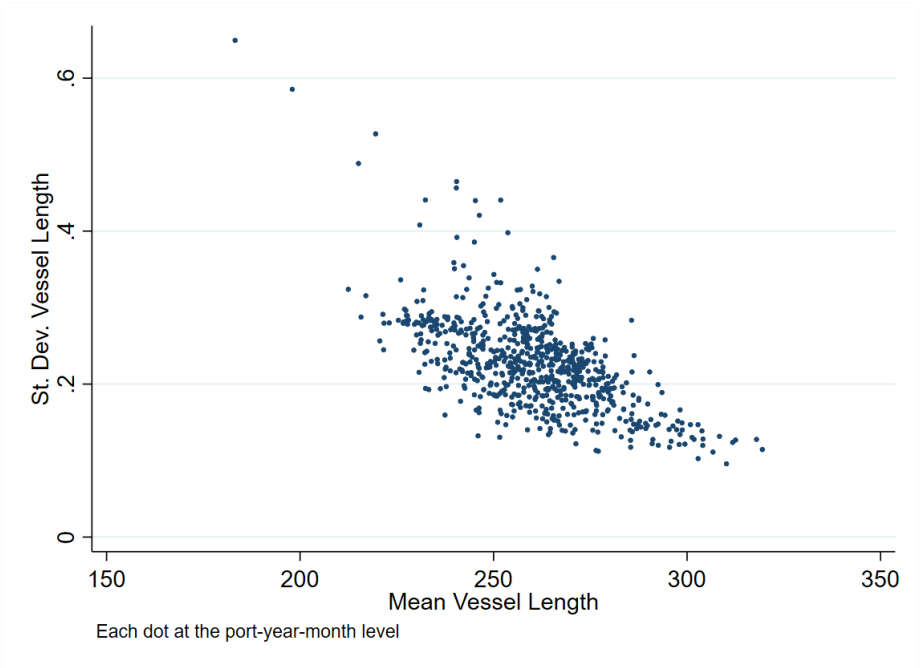


Figure 5: Mean vessel length versus standard deviation