Estimating the effects of the container revolution on world trade[1]

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Abstract

The introduction of containerization triggered complementary technological and organizational changes that revolutionized global freight transport. Despite numerous claims about the importance of containerization in stimulating international trade, econometric estimates on the effects of containerization on trade appear to be missing. Our paper fills this gap in the literature. Our key idea is to exploit time and cross-sectional variation in countries' adoption of port or railway container facilities to construct a time-varying bilateral technology variable and estimate its effect on explaining variations in bilateral product level trade flows in a large panel for the period 1962-1990. Our estimates suggest that containerization did not only stimulate trade in containerizable products (like auto parts) but also had complementary effects on non-containerizables (like automobiles). As expected, we find larger effects on North-North trade than on North-South or South-South trade and much smaller effects when ignoring railway containerization. Regarding North-North trade, the cumulative average treatment effects of containerization over a 20 year time period amount to about 700%, can be interpreted as causal, and are much larger than the effects of free trade agreements or the GATT. In a nutshell, we provide the first evidence for containerization to be a driver of 20th century economic globalization.

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Keywords: containerization, 20th century global transportation infrastructure, the sources of the growth of world trade.

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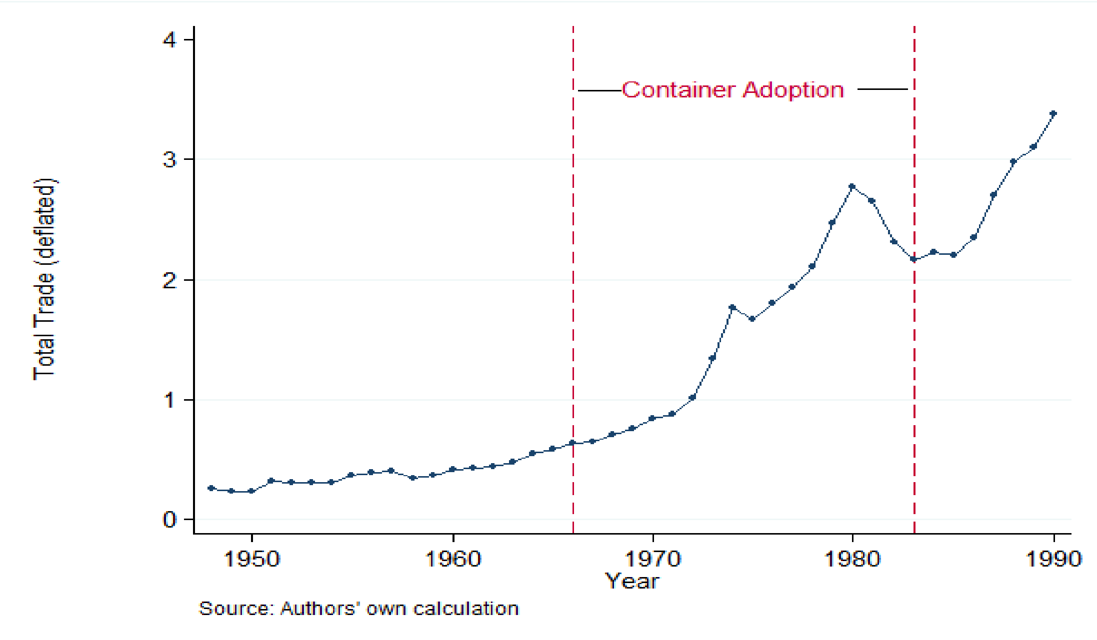
1. Introduction

One of the most striking developments in the global economy since World War II has been the tremendous growth in international trade. As shown in Figure 1, the increase in world trade accelerated dramatically during the early 1970s, with world trade growing in real terms from 0.45 trillion dollars in the early 1960s to 3.4 trillion dollars in 1990, by about a factor of 7. A central question is what accounts for this dramatic growth in world trade. Two broad explanations have been identified: (i) trade policy liberalization and (ii) technology-led declines in transportation costs.

Figure 1: The growth of world trade (deflated): 1948-1990



A vast literature on transportation economics has argued that containerization was the major change in 20th century transportation technology responsible for the acceleration of the globalization of the world economy since the 1960s.[3] Figure 1 reveals that the dramatic increase in the growth in world trade coincides indeed with the period of global container adoption in international trade which occurred between 1966 and 1983. However, a quantitative assessment on the effect of containerization on international trade appears to be missing. In fact, in an influential and well-searched book on the history of the container revolution, Mark Levinson (2006, p.8) asserts that "how much the container matters to the world economy is impossible to quantify". Our paper challenges this claim and suggests an empirical identification strategy that allows us to estimate the effect of containerization on international trade.

[3]See Levinsohn (2006) and Donovan and Booney (2006) for good overviews of containerization and references to case studies on the effects of containerization from a business history perspective.

Containerization was invented and first commercially implemented in the US in the mid 1950s. After ten years of US innovation in port and container ship technologies, followed by the international standardization in 1965, the adoption of containerization in international trade started in 1966. Numerous case studies have documented that containerization has not only effected the operation and relocation of ports but the entire transportation industry.[4] Specifically, the introduction of containerization has gone hand in hand with the creation of the modern intermodal transport system, facilitating dramatic increases in shipping capacities and reductions in delivery times through intermodal cargo movements between ships, trains and trucks.

Based on information scattered in transportation industry journals, we are able to identify the year in which a country entered the container age by first processing cargo via port and railway container facilities. Since the adoption of container technology resulted in complementary changes that transformed an economy's entire transportation industry, we capture containerization as a country-pair specific qualitative technology variable that switches from 0 to 1 when both countries entered the container age at time *t*. Time and cross-sectional variation of this technology variable permits us to apply it to a large panel of bilateral trade flows for 157 countries during the time period of 1962-1990. Our time horizon includes 4 years of pre-container shipping in international trade, the period of global container adoption 1966-1983 and 7 years where no new country in our sample started to adopt containerization. Since our time horizon precedes the period of dramatic reductions in the costs of air transport, our study excludes the other major 20th century change in the global transportation sector. Instead our data provides information on both port and railway containerization, our analysis captures the main modes of international transport during this period.[5]

The panel nature of our data set permits us not only to estimate the cumulate average treatment effects (ATE) of containerization but also allows us to evaluate the size of the estimates in comparison to the time-varying trade policy liberalization variables that have been used in the literature. The inclusion of country-and-time effects allows us to capture multi-lateral resistance identified by the structural gravity literature and other time-varying factors that might be correlated with countries' decisions to invest in container ports. Difficult to measure geographic factors, like government desires to act as container port hubs, are captured by country-pair specific fixed effects.

[4] See McKinsey, (1967, 1972) and the various issues in Containerization International (1970-1992).

[5] Since the adjustment of container transportation via truck followed the adoption of port and railway container facilities we capture the main modes of cargo transport during this period.

The period of international container adoption coincided with major reductions of economy-wide activity triggered by the dramatic changes in the price of crude oil, which increased by over 650 percent between 1972 and 1980. The 1970s oil crisis and the accompanying government policy measures aimed at reducing aggregate consumption will mask the effects of container adoption on aggregate trade flows. For this reason and because not all products are containerizable, we examine variations in bilateral trade flows at a disaggregated level. This allows us to exploit a 1968 study by the German Engineers Society which classifies 4-digit product groups as to whether they were suitable for container shipments as of 1968. Restricting our sample to North-North trade, our benchmark specification suggests that the cumulative average treatment effect (ATE) of containerization was about 700% over a 20-year time period following its bilateral adoption. A statistically insignificant pre-treatment effect suggests that the estimates can be given a causal interpretation. Although we find larger effects on containerizable than non-containerizable, the difference is not statistically significant. This can be interpreted that container technology not only increase trade in containerizable goods (intermediates like auto parts) but had complementary effects by also increasing the trade in goods that are not containerizable (assembled automobiles). Expanding the analysis to the world sample, we find that the average treatment effects are cut by half. Although the contemporaneous effect of containerization is quite similar to the North-North analysis, the dynamic effects of containerization are much weaker for trade flows that involve developing economies. The presence of a statistically significant pre-treatment effect suggests anticipation effects of containerization when involving late adopters. Across all specifications we find stronger effects when considering 'port or railway containerization' versus 'port alone containerization' and also much larger effects of the container variable compared to the trade policy liberalization variables.

Our paper contributes to the broader literature that aims to quantify the effects of changes in transportation technology on economic activity. Starting with Fogel's (1964) pioneering study on the effects of US railroads on economic growth, a number of studies have investigated the effects of railroad construction on economic performance and market integration. Based on detailed archival data from colonial India, Davidson (2010) provides a comprehensive general equilibrium analysis of the impacts resulting from the expansion of India's railroad network during 1853-1930.[6] While the introduction of rail and steamships were the main changes in transportation technology that underpinned the

[6] Davidson (2010) tests several hypotheses of the effects of railroads that he derives from a multi-region, multi-commodity Ricardian trade model. Hurd (1975) follows Fogel (1964) in applying a social savings methodology to estimate the impacts of Indian railroad construction.

first wave of globalization (1840s-1914), students of transportation technology and prominent commentators link the post World War II growth of world trade to containerization. For example, Paul Krugman writes (2009, p. 7):

> *"The ability to ship things long distances fairly cheaply has been there since the steamship and the railroad. What was the big bottleneck was getting things on and off the ships. A large part of the costs of international trade was taking the cargo off the ship, sorting it out, and dealing with the pilferage that always took place along the way. So, the first big thing that changed was the introduction of the container. When we think about technology that changed the world, we think about glamorous things like the internet. But if you try to figure out what happened to world trade, there is a really strong case to be made that it was the container, which could be hauled off a ship and put onto a truck or a train and moved on. It used to be the case that ports were places with thousands and thousands of longshoremen milling around loading and unloading ships. Now longshoremen are like something out of those science fiction movies in which people have disappeared and been replaced by machines".*

The current state of the empirical trade literature does not appear to support the view that the decline in transportation costs played a significant role in the growth of world trade. In an influential paper studying the growth of world trade, Baier and Bergstrand (2001) have found that the reduction in tariffs is more than three times as important as the decline in transportation costs in explaining the growth of OECD trade between 1958-60 and 1986-88.[7] In his survey of how changes in transportation costs have affected international trade in the post world War II period, Hummels (2007) has detected an actual increase in ocean shipping rates during 1974-84, a period after the adoption of containerization in the US. Using commodity data on US trade flows, Hummels finds that freight cost reductions from increasing an exporter's share of containerized trade have been eroded by the increase in fuel costs resulting from the 1970s hike in oil prices.[8]

Our findings of a strong effect of containerization is reconciled by recognizing that our identification strategy focuses on the adoption of intermodal transportation (port and railway) at the economy wide level and allowing for dynamic adjustments. In fact,

[7] Because of data limitations, Baier and Bergstrand (2001, Table 1, p.14) use only a multi-lateral rather than a bilateral index of changes in transportation costs. Their index suggests that Austria's transportation costs versus the rest of the world has actually increased between 1958 and 1986, which does not appear plausible. Although land-locked, Austria has been an early entrant in the container age through their construction of container railway terminals in 1968 which connected it to the main container ports in Europe.

[8] Another study that investigates the effects of containerization on US imports in the post adoption period is Blonigen and Wilson (2008). Building on Clark, Dollar and Micco (2004), they estimate the effects of port efficiency measures on bilateral trade flows and find that increasing the share of trade that is containerized by 1 percent lowers shipping costs by only 0.05 percent.

our findings confirm Hummels' (2007, p. 144) intuition that "*the real gains from containerization might come from quality changes in transportation services…To the extent that these quality improvements do not show up in measured price indices, the indices understate the value of the technological change*". Our findings are also compatible with Yi (2003) who has stressed the role of vertical specialization and disintegration of production as a major factor in explaining the growth of world trade.[9] Experts in transportation economics have emphasized repeatedly that the global diffusion of intermodal transport was a prerequisite for the disintegration of production and the establishment of global supply chains (Notteboom and Rodrigue, 2008).

The next section of the paper provides a historical discussion on the origins and effects of containerization. Our historical narrative fulfills two purposes. First, by describing the effects of the different channels through which container adoption reduced trade costs we point to the mechanism that underlies our causal claim. Second, our historical evidence on the speed of diffusion of container technology with an economy provides the rationale for our identification strategy of capturing containerization. Section three introduces our empirical specifications and discusses our empirical findings. Section four concludes.

2. The container revolution and intermodal transport

> *"Born of the need to reduce labor, time and handling, containerization links the manufacturer or producer with the ultimate consumer or customer. By eliminating as many as 12 separate handlings, containers minimize cargo loss or damage; speed delivery; reduce overall expenditure".*
> *(Containerisation International, 1970, p. 19)*

2.1 Historical background

Before the advent of containerization, the technology for unloading general cargo through the process of *break-bulk* shipping has hardly changed since the Phoenicians traded along the coast of the Mediterranean. The loading and unloading of individual items in barrels, sacks and wooden crates from land transport to ship and back again on arrival was slow and labor-intensive. Technological advances through the use of ropes for bundling timber and pallets for stacking and transporting bags or sacks yielded some efficiency gains, but the handling of cargo was almost as labor intensive after World War II as it was during the beginning of the Victorian age. From a shipper's perspective, often two-third's of a ship's productive time was spent in port causing port congestion and low

[9] Baier and Bergstrand (2001) are quite honest in pointing out that their final goods framework excludes this potential source of the growth of world trade.

levels of ship utilization. Following the spread of the railways, it became apparent already during the first era of globalization that the bottleneck in freight transport was at the interface between the land and sea transport modes.

Before World War II, US, British and French railway companies experimented with methods of sealing goods in different sizes and shapes of boxes before transporting them. However, the lack of specialized capital equipment like specialized cranes for loading and loading combined with union resistance to changes in work practices at the docks delayed the development of container shipping until the mid 1950s.

The genesis of the container revolution goes back to April 26, 1956 when the *Ideal- X,* made its maiden voyage from Port Newark to Houston, Texas. The ideal X was a converted World War II tanker that was redesigned with a reinforced deck to sustain the load of 58 containers. As so common in the history of innovation, the breakthrough of containerized shipping came from someone outside the industry, Malcolm McLean, a trucking entrepreneur from North Carolina. Concerned about increased US highway congestion in the 1950s when US coastwise shipping was widely seen as an unprofitable business, McLean's central idea was to integrate coastwise shipping with his trucking business in an era where trucking and shipping were segmented industries. His vision was the creation of an integrated transportation system that moved cargo door-to door directly from the producer to the customer. The immediate success of the first US container journey resulted from the large cost savings from the mechanized loading and unloading of containerized cargos. Shortly after the *Ideal-X* docked at the Port of Houston, McLean's enterprise, which later became known as Sea-Land Service, was already taking orders to ship containerized cargo back to Newark.

The 1956 container operation by the *Ideal X* involved a ship and cranes that were designed for other purposes. McLean's fundamental insight, which was years ahead of his time, was that the success of the container did not rest simply in the idea of putting cargo into a metal box. Instead, it required complementary changes in cranes, ships, ports, trucks, trains and storage facilities. Three years following *Ideal X's* maiden voyage, container shipping saw additional savings through the building of purpose-built container cranes followed by the building of large purpose-built containerships. On January 9, 1959 the world's first purpose-built container crane started to operate and was capable of loading one 40,000-pound box every three minutes. The productivity gains from using this container crane were staggering, as it could handle 400 tons per hours, more than 40 times the average productivity of a longshore gang.[10] Investment in larger shipping

[10] See Levinson (2006, p. 65).

capacity became now profitable since containerization dramatically reduced a ship's average time in ports.

Given the large investment costs, industry experts revealed a considerable amount of uncertainty and skepticism regarding the success of the container technology at the time. Many transportation analysts judged container shipping as a niche technology and did not anticipate the dramatic transformations that this technology was about to bring to the entire domestic and international transportation sector. In the first decade following the *Ideal- X'*s maiden voyage, innovation and investment in container technology remained an American affair. But, as Levinson (2006, p. 201) points out, "ports, railroads, governments, and trade unions around the world spent those years studying the ways that containerization had shaken freight transportation in the United States". The early initiatives came from US shipping lines and by the early 1960s, containerization was firmly established on routes between the US mainland and Puerto Rico, Hawaii and Alaska. Ten years of US advancement in container technology set the foundation for containerization to go global in 1966.[11] In that year, the first container services were established in the transatlantic trade between the US and European ports in the UK, Netherlands and West Germany.

2.2 Economic effects of containerization

From a transportation technology perspective, containerization resulted in the introduction of intermodal freight transport, since the shipment of a container can use multiple modes of transportation -ship, rail or truck- without any handling of the freight when changing modes. By eliminating sometimes as many as a dozen separate handlings of the cargo, the container resulted in linking the producer directly to the customer. Since containerization resulted in a reduction of the total resource costs of shipping a good from the (inland) manufacturer to the (inland) customer, its impact is not adequately captured by looking at changes in port to port freight costs.[12]

Containerization started as a private endeavor by the shipping lines. In the early stages, shipping lines had to bear most of the costs since many ports such as New York and London were reluctant to spend significant funds on 'a new technology' with uncertain returns at the time. Many shipping lines had to operate from small and formerly

[11] Australia was the first country to follow the US and adopted container technology in 1964, but not in international trade.

[12] Reliable data on comparable changes in door-to-door and ocean freight rates before and after containerization are not available. However, Eyre (1964) uses data from the American Association of Port Authorities to illustrate the composition of estimated door-to-door costs of shipping one truckload of Medicine from Chicago to Nancy (France) in the pre-container age. Astonishingly, ocean shipping amounted only 24.4% of total costs, whereas total port costs constituted 48.7%, freight to the US port city 14.3%, European inland freight 8.6% and local freight in port vicinity 4%. This supports the view that the bulk of costs savings from containerization stemmed from efficiency gains in the sea-land interface.

unknown ports and install their own cranes. The process was extremely expensive. After the container proved to be successful, ports warmed up to containerization and a race started among ports to attract the most shipping lines by building new terminals and providing the infrastructure to handle containers. Containerization required major technological changes in port facilities, which often led to the creation of new container ports. In the United States, the new container ports in Newark and Oakland took business from traditional ports like New York and San Francisco. In the UK, the ports of London and Liverpool, which handled most of the British trade for centuries lost their dominant position to the emerging container ports of Tilbury and Felixstowe.

In many countries, port authorities fall under the administration of the government. Because of the high costs, careful planning and analysis had to be undertaken by governments to study the feasibility of containerization. In the UK, the government commissioned McKinsey (1967) to conduct a cost and benefit analysis before spending significant public funds on container port facilities. Five years later, McKinsey (1972) provided a quantitative assessment of the effects of containerization following the first five years after its adoption in the UK and Western Europe. Table 1 provides a summary of the sources and magnitude of resource savings from the adoption of container technology between 1965 and 1970/71.

Table 1: Effects of containerization (UK/Europe)

	Pre-container: 1965	**Container: 1970/71**
Productivity of dock labor	1.7 (tons per hour)	30 (tons per hour)
Average ship size	8.4 (average GRT)	19.7 (average GRT)
Port concentration (number of European loading ports, southbound Australia)	11 ports	3 ports
Insurance costs (Australia-Europe trade for imports)	£0.24 per ton	£0.04 per ton
Capital locked up as inventory in transit (Route: Hamburg-Sydney)	£2 per ton	£1 per ton

Source: Authors' own compilation from various sources in McKinsey (1972).

One of the major benefits of containerization was to remove the bottleneck in freight transport in the crucial land-sea interface. The construction of purpose-designed container terminals increased the productivity of dock labor from 1.7 to 30 tons per hour (Table 1). Improvement in the efficiency and speed of cargo handling allowed shipping companies to take advantage of economies of scale by more than doubling the average ship size. The resulting increase in port capacity provided opportunities and pressures for the inland distribution of maritime containers. In the UK the introduction of railway container terminals went in tandem with port containerization and by 1972 the Far East service alone already operated trains between an ocean terminal and six inland rail terminals.

In the pre-container age, port managers handled and organized the trade of their own industrial hinterlands. With the railways taking over the inland distribution, containerization eliminated the notion of a port hinterland and containerized freight became concentrated in a few major terminals. For example, whereas in 1965 ships in the (southbound) Australian trade called at any of 11 loading ports in Europe, by 1972 the entire trade was shared among the three ports of Hamburg, Rotterdam and Tilbury. Within a few years, a hub-and-spoke system already emerged.

A major benefit of sealing cargo at the location of production in a box to be opened at the final destination is that it reduced the pilferage, damage and theft that were so common in the age of break-bulk shipping. A common joke at the New York piers was that the dockers wages were “twenty dollars a day and all the Scotch you could carry home”. The resulting reduction in insurance costs from containerization was considerable. On the Australia-Europe trade, between 1965 and 1970/71 the insurance costs fell from an average of 24 pennies per ton to 4 pennies per ton (Table 1).

Intermodal transport also decreased the time in transit between cargo closing and availability. Containerization cut the journey between Europe and Australia from 70 to 34 days. Given that the average cargo at the time was worth about £60 per ton and assuming that the opportunity cost of capital tied up in transit is about 15%, the 36 day improvement cut the capital cost of inventory by about a half (Table 1).

The importance of labor in the operation of ports in the pre-containerization age resulted in the emergence of strong labor unions, which resisted not only labor-saving organizational changes but were also well-organized and effective in calling for strikes. The replacement of capital for labor, which emerged through containerization, ended the frequent delays and uncertainties in shipping caused by these strikes.

2.3 Diffusion of container technology

The early use of containers was driven by private shipping companies who used container sizes and loading devices that best fit their cargo and shipment routes. The first fully containerized ships used 35 foot containers, which was the maximum allowable length for truck traffic on US highways. However, since a fully loaded container of this size was too heavy for a crane to lift, other companies used much smaller sizes which could be much easier stacked and moved with forklifts. A major force for the international adoption and diffusion of container technology was the standardization of container sizes. The standardization process was initiated in the US by the Federal Maritime Board and involved stake holders from the maritime sector, truck lines, railroads and trailer manufacturers. In 1961, the Federal Maritime Board established the standard nominal dimension of containers - 8 feet wide, 8 feet high and 10, 20, 30 and 40 feet long- and announced that only containerships designed for these sizes were able to receive construction subsidies from the US government.

Following the setting of standards in the US, the International Standards Organization (ISO) started to study containerization with the purpose of establishing worldwide guidelines as a prerequisite for firms and governments investing in internationally compatible container technology. Following a compromise between US and European interest groups, the ISO formally adopted the 10- ,20- , 30- and 40-foot containers plus a few smaller sizes favored by the Europeans as ISO standards in 1964. Besides container size, strength requirements and lifting standards were other major aspects the ISO was able to standardize in 1965. The standardization of container technology was followed by the rise of container leasing companies who had now the incentives to expand their fleets and allowing shippers the flexibility to lease containers and therefore significantly reducing the fixed costs of using this technology. The ability for land and sea carriers to handle each others' containers in different locations set the foundation of global container adoption around the globe.

The adoption of container technology in international trade started in 1966 and the period of 1966-1983 has been labeled by geographers as the era of global diffusion of container technology around the globe (Kuby and Reid, 1992).[13] The introduction of container technology started with a country's investment in container port facilities but quickly progressed to engulf other parts of the transportation network, like rail and road

[13] According to Kuby and Reid (1992, p.285) "…after 1982 the industry reached maturity, characterized by low margins and greatly improved services….the containerization trend stabilized between 1985 and 1988, as near-saturation of the new technology occurred."

transport. Accompanying technological changes were larger ships and trains and increased use of computers and telecommunications for managing and tracking intermodal movement.

From our calculations of an underlying sample of 157 countries, 122 entered the container age by first processing container cargo via port or railway facilities between 1966 and 1983 while 35 countries remained uncontainerized as of 1990. Appendix Table 1 lists all sample countries and reveals considerable cross-sectional and time variation of countries' adoption of container port facilities during the sample period.

How quickly did containerization diffuse through an economy's transportation sector following its initial adoption of container port facilities? In answering this question, two things need to be recognized. First, some tradable goods like assembled automobiles, heavy machinery, construction equipment and some steel products can't be put into containers. Second, technological advancement in container technology has expanded the range of containerizable products over time. For example, initially food products were not containerizable, but through the development of refrigerated containers, food became containerizable in later years. A measure of the *degree of container utilization* of the international transportation system of an economy i at time t, is then the ratio of the economy's traded containerized cargo over its traded containerizable cargo,

$$\text{container utilization}_{it} = (\text{traded containerized cargo}_{it})/(\text{traded containerizable cargo}_{it}) \quad (1)$$

Fortunately, the denominator of (1) can be calculated based on a study by the *Verband deutscher Ingenieure* (German Engineering Society) which classified 4-digit SITC industries according to whether they were suitable for containers as of 1968.[14] The calculation of (1) faces the challenge that containers can cross borders through different modes of transport (sea, rail, truck and air) and that there exist no data on traded container tonnage via rail, trucks or air. However, for island economies like the UK and Japan, where (at the time) the majority of international trade went through sea ports, it is possible to trace their growth of container utilization following their first adoption of the technology.[15] For these two countries, (1) can be calculated by combining data on container tonnage going through sea ports available from *Containerisation International* with tonnage of trade in containerizable industries provided by the *OECD International Trade by Commodity Statistics*.

[14] The engineering study classifies industries into Class A: suitable for containers, Class B: goods of limited suitability for containers and Class C: goods not suitable for containers as of 1968. For the purpose of constructing our container utilization index, we only include goods in Class A as containerizable.
[15] Between 1965 and 1979, 99% of UK trade went through sea ports.

Figure 2: Changes in container utilization in the UK and Japan

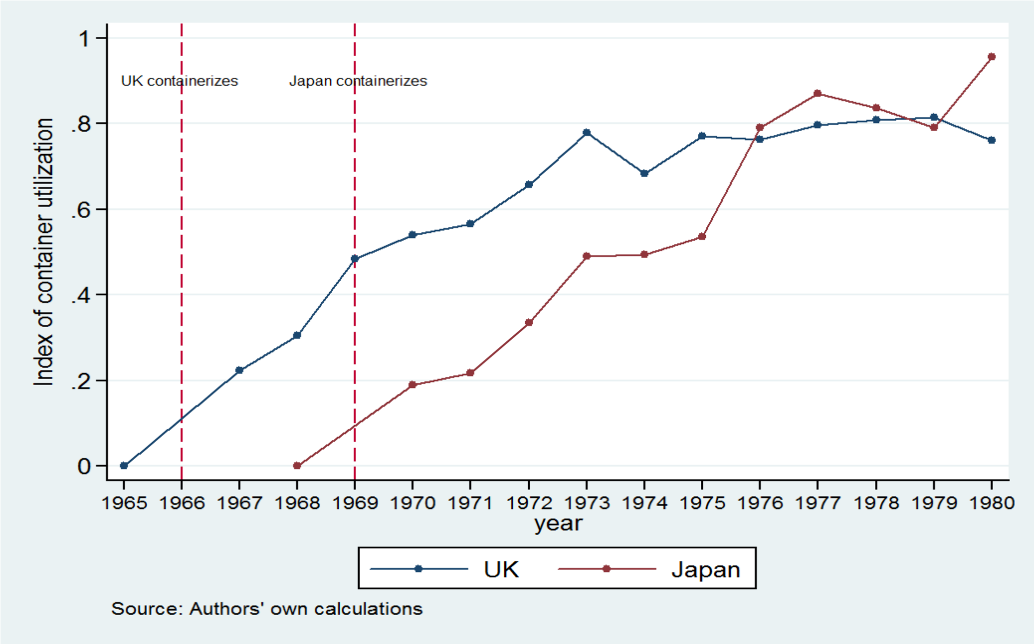


Figure 2 depicts the index of container utilization in international trade for the UK and Japan during the period of 1965-1979. [16] The UK adopted its first container facilities in 1966 and the technology diffused quite rapidly. The utilization grows from 20% in 1967 to about 80% in 1973 and remains then quite flat, which can be explained by the oil shock and the recession following the oil crisis. The picture for Japan is quite similar. Japan adopted containerization in 1969 and the utilization index grows from 20% in 1970 to 80% in 1976.

2.4. Containerization and land transport

A defining element of the adoption of container technology is the creation of intermodal transport. Containerization was quickly picked up by railways in different countries. For example, in response to port containerization, and in an effort to avoid being left out, the railways of Europe came together in 1967 and formed *Intercontainer*, The International Association for Transcontainer Traffic. This company was formed to handle containers on the Continent and compete with traditional shipping lines.[17]

[16] Total trade is defined as (exports+imports)/2. Because of missing data in the years of container adoption, the graph depicts linear segments between 1965 and 1967 for the UK and between 1968 and 1970 for Japan.
[17] At the time, British Rail was already operating a cellular ship service between Harwich, Zeebruegge and Rotterdam and a freightliner service between London and Paris. Initially 11 European countries formed Intercontainer and were later joined by 8 more.

Railway containerization allowed landlocked countries like Austria and Switzerland to ship their goods in containers to sea ports in neighboring countries destined to overseas destinations. In many cases, this was cheaper and less laborious than road transportation. In a comprehensive cost study for the UK, McKinsey (1967) calculated that container transport was cheaper by rail than truck for journeys above 100 miles. *Containerisation International* (1972) estimated that the cost of moving 1 TEU (twenty foot equivalent unit container) between Paris and Cologne in 1972 was about 75% of the equivalent road costs.

Although the majority of non-land locked countries adopted railway container facility after their introduction of container sea ports, for some the ordering was reversed. For example, Norway entered the container age via their railway network in 1969, five years before the adoption at their sea ports. This suggests that countries could enter the container age either through the introduction of either rail or sea ports container facilities. In the subsequent analysis we investigate the differential effects of sea port only containerization and sea or railway containerization.

3. Empirical implementation

3.1. Quantifying containerization

Our objective is to estimate the effect of containerization on international trade. The key question that arises is how to capture this technological change quantitatively. Since the adoption of container technology triggered complementary technological and organizational changes that affected an economy's entire transportation suggests to quantify this technological change at the economy level. If data on the international shipments via rail or truck were available and the containerizability of an industry were fixed over time, the container utilization index (1) would be a sensible measure of the technological change. However, because of the absence of the appropriate data and the occurrence of technological change regarding containerizability, we can't go this path. Alternatively, the quick rise in the container utilization for the UK and Japan justifies to quantify containerization by a qualitatively variable that switches from 0 to 1 when country i enters the container age at time t. Entrance into the container age can occur through the first use of either sea ports or inland railway ports. An advantage of this specification is that it captures the intermodal aspect of containerization since it encompasses land-locked countries like Austria and Switzerland who entered the container age via rail connection to the container sea ports of Rotterdam and Hamburg. Based on the information provided in the published volumes of *Containerisation*

International between 1970 and 1992, we construct a time-varying container adoption variable for country i, $adoptcont_{it}$, defined as:

$$adoptcont_{it} = \begin{Bmatrix} 1 \;\; if\ country\ i\ uses\ sea\ or\ rail\ container\ ports\ in\ year\ t \\ 0 \quad otherwise \end{Bmatrix}$$

(2)

Although a country's adoption of container technology is expected to have some effect on its overall trade, the nature of container technology suggests that containerization is more adequately captured in a bilateral trading context since this allows us to specify the presence of container technology of a country's trading partner. This suggests to capture containerization by a time-varying bilateral technology variable, defined as:

$$fullcont_{ijti} = \begin{Bmatrix} 1 \;\; if\ i\ and\ j\ have\ both\ containerized\ ports\ or\ railways\ \ in\ year\ \ t \\ 0 \qquad\qquad otherwise \end{Bmatrix}$$

(3)

From an econometric point of view, there are several advantage quantifying containerization by a time-varying bilateral variable. Since we are interested in exploring causal effects of container technology on trade, one worries about potential selection bias in the adoption of container technology. Armed with "ex post" knowledge that containerization revolutionized global freight transport, one would be inclined to infer that countries that initially traded a lot would be most likely to adopt container technology. However, as we have pointed out in our historical narrative in section 2, from the relevant decision point of view of the 1960s, containerization was by many viewed as a niche technology with highly uncertain global impact. This line of reasoning has been substantiated by a recent study by Rua (2012) who has found that a country's share of world trade does not always have a significant effect on its likelihood to adopt containerization.[18] Given that a country's trade share did not necessarily affect its decision to containerize, the bilateral technology adoption variable $fullcont_{ijt}$ is likely to be characterized by even a higher degree of serendipity than the unilateral adoption variable $adoptcont_{it}$.

[18] Rua (2012) also finds that labor costs and trade with the US to have a neutral or negative effect on the adoption of containerization. This implies that adoption decisions were not necessarily driven by economic fundamentals.

Given the important role of maritime trade in overall trade we also examine the sole impact of port containerization by defining a port containerization variable $portcont_{ijt}$ as:

$$portcont_{ijt} = \begin{cases} 1 & if\ i\ and\ j\ have\ both\ containerized\ seaports\ in\ year\ t \\ 0 & otherwise \end{cases} \quad (4)$$

3.2 Research design and empirical specification

The time frame of our analysis is dictated by the availability of bilateral trade data at the product level and the timeline of container adoption in international trade. Fortunately, the world trade data set compiled by Feenstra et al. (2005) goes back to 1962 and covers bilateral trade flows from 1962-2000 at the 4-digit product level.[19] Since the adoption of containerization in international trade started in 1966 and ended in 1983, we chose 1962-1990 as our sample period, which includes 4 years prior to the first adoption and 7 years past the last adoption year. We chose to exclude the 1990s because of both the redrawing of the political map after the end of the Cold War and the reduction in the costs of air transport which started to kick in in the early 1990s. Although there is limited data on changes in the mode of transport in international trade, a reading of the transportation industry literature suggests that during our chosen sample period containerization was the main technological changing affecting the three major modes of transport (sea, rail and road) in international trade.

Our next consideration is the nature of our outcome variable. Given that containerization might have different effects on different product lines, we examine variations in bilateral trade flows at the 4-digit product level and control for product-specific changes by time-varying product fixed effects. An advantage of this approach is that it allows us to estimate the effects of containerization on containerizable products relative to its effects on all products. For that purpose, we take advantage of the 1968 study by the German Engineer's society, reported in *Containerisation International Yearbook* (1971), which classifies 4-digit product lines whether they are suitable for container shipments as of 1968.[20] So our dependent variable pertains to the bilateral trade

[19] The data set is constructed from the United Nations trade data and is available from NBER.

[20] Recall that we used this classification of our utilization index (1) used in Figure 2. A caveat in applying this classification on a longer time period is that it is based on the state of container technology in 1968. Although we have learned that some sectors, like food, have become containerizable in the 1970s, we are not aware of any systematic study which traces changes in containerizability over time.

flow from country i to country j in product group k at time t, x_{ijkt}. Our empirical equation to be estimated is then given by:

$$\ln x_{ijkt} = \beta_0 + \beta_1 Cont_{ijt} + \beta_2 \overrightarrow{Policy_{ijt}} + \beta_3 \overrightarrow{D_{ijkt}} + u_{ijkt}, \quad (5)$$

where $Cont_{ijt}$ pertains to one of the container variables defined in (3) and (4), $\overrightarrow{Policy_{ijt}}$ pertains to a vector of time-varying bilateral policy variables, $\overrightarrow{D_{ijkt}}$ includes a (large) vector of country- time and product-time specific fixed effects and u_{ijkt} denotes the error term.

An attractive feature of our panel specification is that it allows us to examine the dynamic aspects of containerization over a time period 1962-1990 characterized, as argued above, by little other technological changes affecting international trade. Following the advice of the panel literature (Woolridge, 2000) we examine changes in trade flows at 5 year intervals. In our context, the advantage of focusing on 5 year variations is that it mitigates the effect of differences in the speed of adoption (recall Figure 2) as well as allowing time for the build-up of the intermodal transport system. We estimate equation (5) on 7 time periods: 1962, 1967, 1972, 1977, 1982, 1987 and 1990.

To our knowledge, (5) is the first specification in the literature that identifies a time-varying bilateral technological change and aims to estimate its impact on international trade. An advantage of this specification is that allows for a comparison to other time-varying bilateral policy changes for a country pair *i* and *j*, like entrance into a free trade agreement (FTA) or both being a member in the GATT, which have been treated extensively in the literature. Specifically, (5) allows for a horse race between our container technology variables and these trade liberalization variables. A key difference of the container variable is that it reflects a mixture of private and public sector decision making and the bilateral containerization occurrence is arguably based on a larger degree of serendipity than the trade policy variables.

An advantage of our panel specification is that it allows us to use fixed effects to avoid omitted variable biases associated with multi-lateral resistance terms identified from the structural approach to gravity.[21] Specifically, the inclusion of time-varying

[21] See Bergstrand and Egger (2011) and Feenstra (2004, chapter 5) for good surveys of the gravity literature.

importer (*it*), exporter (*jt*) and product (*kt*) fixed effects in $\overrightarrow{D_{ijkt}}$ capture time-varying product and country-specific factors that are either difficult to pin down or measure.[22]

We opted for first differencing the data across our 5-year time periods such that our dependent variable becomes $\text{dln}\boldsymbol{x}_{\boldsymbol{ijk,t-(t-1)}}$. Woolridge (2002, chapter 10) suggests that first-differencing a panel data set yields advantages if unobserved heterogeneity in trade flows is correlated over time. In our context, by differencing the data we remove the need to include *ijk* fixed effects and it has also the advantage of not assuming that *ijk* effects are time invariant.[23] So we regress $\text{dln}x_{ij,t-(t-1)}$ on $Cont_{ij,t-(t-1)}$ and the other first differenced country-pair time-variant policy variables like being in a free trade agreement (FTA) or a member in the GATT.

3.3 Empirical findings

Although our entire data set covers a total of 157 countries, we initially restrict our analysis to a sample of 22 industrialized countries, which we denote as North-North trade.[24] Because we expect a quicker and deeper penetration of container technology in industrialized countries (recall Figure 2), we initially apply specification (5) on an empirical domain where our technology variables are expected to capture relatively similar transformations of the transportation sector. In addition, restricting ourselves to North-North trade yields a full panel of country pairs.

Our dependent variable is the log of exports and imports between a country pair i and j in a 4-digit product line k. We only considered observations with trade occurring in at least one direction, and implicitly categorized missing observations with a zero trade flow.[25] The rationale behind this is that bilateral containerization should affect total bilateral trade rather than a specific direction. Because not all country pairs trade the same set of products in all years even in North-North trade, for which the panel is balanced on the 'country-pair dimension', the panel is 'naturally' imbalanced in the product dimension. To examine the potential biases from product imbalances we report results on the 'full sample' and on a 'restricted sample' which includes only products which appear during the whole time period for at least one country pair. The latter can be thought of a

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[22] Since the country-time fixed effects preclude the inclusion of time-varying 'economic mass' variables like GDP and GDP per capita, we refrain from calling our specification a gravity equation.

[23] Also given the limits of available computer power available to us first differencing is a necessary transformation of the data.

[24] Our selection criteria was OECD membership as of 1990. The countries are identified in Appendix Table 3.

[25] In communication with the creators of the data base we were told that the missing observations are really missing. So contrary to what one reads in the empirical trade literature, measurement error appears to be the bigger issue than the prevalence of zero observations.

'more balanced' panel in the product dimension. We also estimate equation (5) both on the subsample of containerizable product lines, based on the 1968 classification of containerizability as discussed in the previous section, and on all product lines.

Table 2 contains the estimates of the different specifications of North-North trade. The upper panel gives the estimates of the full containerization variable (3) and the lower panel of the sea port containerization variable (4). Columns (1)-(3) pertain to the full product sample and columns (4)-(5) to the more balanced panel as discussed above. An advantage of our panel specification is that it allows us to explore the dynamic effects of containerization, which we capture using lagged terms of our main explanatory variable and also of the other co-variates. Overall, the results in Table 2 suggest that containerization had statistically significant and economically large effects on the volume of bilateral trade. The coefficient of the lagged effects reveal that containerization had strong and persistent effects even 20 years after bilateral adoption.

Let's take a closer look at the estimates in our benchmark specification (1) for North-North trade. The estimated coefficient of 1.436 on the *fullcont* variable in the upper panel suggests that the concurrent effect of containerization was to raise bilateral trade flows on average by 320% (=$e^{1.436}$-1) compared to where both countries had not yet adopted the container technology. The coefficients on the lag variables reveal that over the next 5-year periods the effect was 232% (=$e^{1.199}$-1), 156% (=$e^{0.939}$-1) and 82% (=$e^{0.601}$-1) respectively. The cumulative average treatment effect (ATE) of containerization over a 20 year time period amount to a staggering 790%.[26]

How do the effects of containerization compare to the trade policy variables that we include in the regression? As mentioned above we included two sets of time-varying policy variables. The *fta* dummy indicates whether a country pair i,j belonged either to the same regional free trade block or had a free trade agreement in a specific year. The GATT variable switches to 1 if countries i and j are a member of GATT, the precursor of the WTO, at time time t. The inclusion of lagged effects permits us also to investigate the dynamic effects of these variables.

[2626] The cumulative ATE is sum of the concurrent and lagged effects.

Table 2: First differenced panel estimates for North-North trade (with country-time and product-tim fixed effects)

	Full Sample			More Balanced Sample	
	(1) Containerizable	(2) Containerizable	(3) All industries	(4) Containerizable	(5) All industries
Panel A: Full Containerization					
$\Delta fullcont_{ij,t}$	1.436***	1.437***	1.263***	1.612***	1.351***
	(0.106)	(0.106)	(0.0926)	(0.112)	(0.0975)
$\Delta fullcont_{ij,t-1}$	1.199***	1.197***	1.102***	1.302***	1.145***
	(0.0817)	(0.0817)	(0.0708)	(0.0853)	(0.0739)
$\Delta fullcont_{ij,t-2}$	0.939***	0.937***	0.943***	0.974***	0.971***
	(0.0296)	(0.0296)	(0.0260)	(0.0304)	(0.0266)
$\Delta fullcont_{ij,t-3}$	0.601***	0.599***	0.592***	0.596***	0.589***
	(0.0178)	(0.0178)	(0.0157)	(0.0177)	(0.0157)
$\Delta fullcont_{ij,t+1}$		0.0454	-0.0502	0.034	-0.041
		(0.0839)	(0.0737)	(0.0859)	(0.0771)
$\Delta fta_{ij,t}$	0.229***	0.239***	0.230***	0.248***	0.234***
	(0.0195)	(0.0196)	(0.0180)	(0.0204)	(0.0187)
$\Delta fta_{ij,t-1}$	0.123***	0.127***	0.120***	0.117***	0.111***
	(0.0135)	(0.0135)	(0.0124)	(0.0143)	(0.0130)
$\Delta fta_{ij,t-2}$	0.055***	0.055***	0.047***	0.051**	0.043**
	(0.0155)	(0.0155)	(0.0141)	(0.0156)	(0.0141)
$\Delta fta_{ij,t-3}$	-0.040*	-0.040*	-0.042**	-0.041*	-0.042**
	(0.0158)	(0.0158)	(0.0158)	(0.0173)	(0.0157)
$\Delta fta_{ij,t+1}$		0.087***	0.079***	0.110***	0.108***
		(0.0210)	(0.0195)	(0.0234)	(0.0215)
$\Delta GATT_{ij,t}$	0.653***	0.654***	0.846***	0.641***	0.868***
	(0.0931)	(0.0931)	(0.0817)	(0.0980)	(0.0860)
$\Delta GATT_{ij,t-1}$	0.660***	0.663***	0.868***	0.608***	0.853***
	(0.0818)	(0.0818)	(0.0718)	(0.0859)	(0.0753)
$\Delta GATT_{ij,t-2}$	0.535***	0.539***	0.658***	0.542***	0.677***
	(0.0663)	(0.0663)	(0.0580)	(0.0693)	(0.0604)
$\Delta GATT_{ij,t-3}$	0.254***	0.255***	0.335***	0.265***	0.346***
	(0.0365)	(0.0365)	(0.0329)	(0.0380)	(0.0341)
$\Delta GATT_{ij,t+1}$		0.322	0.196	0.162	0.0821
		(0.206)	(0.193)	(0.216)	(0.203)
Obs	143771	143771	189543	131212	174317
Countries	22	22	22	22	22
No. Products	413	413	591	333	485
R^2	0.195	0.195	0.177	0.195	0.176
FE	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt
Total ATE^a	790%	790%	692%	915%	731%
Panel B: Port Containerization					
$\Delta portcont_{ij,t}$	0.620***	0.711***	0.647***	0.767***	0.696***
	(0.0562)	(0.0604)	(0.0555)	(0.0653)	(0.0599)
$\Delta portcont_{ij,t-1}$	0.543***	0.578***	0.581***	0.641***	0.641***
	(0.0429)	(0.0438)	(0.0402)	(0.0466)	(0.0427)
$\Delta portcont_{ij,t-2}$	0.617***	0.629***	0.655***	0.673***	0.695***
	(0.0265)	(0.0267)	(0.0238)	(0.0273)	(0.0243)
$\Delta portcont_{ij,t-3}$	0.399***	0.402***	0.394***	0.409***	0.400***
	(0.0179)	(0.0179)	(0.0160)	(0.0179)	(0.0160)
$\Delta portcont_{ij,t+1}$		0.217***	0.169**	0.139*	0.111
		(0.0627)	(0.0577)	(0.0672)	(0.0622)
3-lags of GATT and fta	Yes	Yes	Yes	Yes	Yes
1st lead of GATT and fta	No	Yes	Yes	Yes	Yes
Obs	143771	143771	189543	131212	174317
Countries	22	22	22	22	22
No. Products	413	413	591	333	485
R^2	0.191	0.191	0.177	0.191	0.172
FE	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt
Total ATE^a	292%	319%	311%	352%	340%

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[a] Total ATE is the sum of statistically significant container estimates.

We find that the estimated effects of containerization are generally much bigger than trade policy variables. The concurrent and the first two lags of the *fta* variable have the expected positive sign and are highly significant; the third lag is negative but is also imprecisely estimated. The concurrent effect of a free trade agreement is to raise trade by an average of 26% (=$e^{0.229}$-1), which is less than 10% of the concurrent effect of full containerization. The coefficients on the lags of the *fta* variable reveal that over the next 5-year periods the effect was 13% (=$e^{0.123}$-1) and 6% (=$e^{0.0545}$-1) respectively. The cumulative ATE of a free-trade agreement amount then to 45%. It is reassuring that our estimated fta coefficient on these industry-level regressions are roughly the same as the estimate provided by Baier and Bergstrand (2007, p.91), who consider a panel data on aggregate trade flows.

The concurrent and three lag effects of the GATT are all statistically significant and lie in economic magnitude between the container and the *fta* variables. The concurrent effect of bilateral GATT membership is to raise trade by an average of 92% (=$e^{0.653}$-1), which is less than a third the concurrent effect of full containerization. The coefficients on the lags of the GATT variable reveal relatively persistent long-term effects, 10+ years following bilateral membership. Over the next 5-year periods the effect was 93% (=$e^{0.660}$-1) and 71% (=$e^{0.535}$-1) respectively, before dropping to 29% (=$e^{0.254}$-1). The cumulative ATE of GATT membership for bilateral trade is then estimated to amount to 285%, considerably higher than the average effect on free trade agreements, but less than half the accumulated effect of containerization.

A key objective of our paper is to examine the causal effects of containerization on international trade. Our historical narrative and discussion in section 3.1 have suggested if not randomness but an element of serendipity in the determination of our container variable (2). The panel nature of our data puts us in a position to formally test for strict exogeneity of our technology variable. Following the advice of Woolridge (2002, p. 285), we add a future change of *fullcont* in our regression equation (5). The size and statistical significance of this variable can be viewed as a falsification test for whether the container variable captures the effect of the introduction of this new transportation technology rather than any trend to bilateral trade that was also present prior to the adoption of containerization. If the effect captured by the container dummy were simply related to trends already present in trade between that country-pair, we would expect the coefficient on years prior to the adoption of the container to be as large and significant as the coefficient on our variable of interest.

Specification (2) includes a pre-treatment variable on *fullcont* and the other bilateral co-variates *rta* and *GATT*. Since the coefficient of $\Delta fullcont_{ij,t+1}$ is both statistically insignificant and also very small (0.0454) compared to the coefficient of $\Delta fullcont_{ij,t}$ and the other three lagged variables suggests that our estimates provide strong evidence of a causal effect of containerization in the North-North sample. In comparison, the coefficient of the pre-treatment variable $\Delta fta_{ij,t+1}$ is both statistically significant and estimated to be 0.087, suggests the presence of anticipation effects of regional trade agreements. Although the estimated coefficient of the pre-treatment variable $\Delta GATT_{ij,t+1}$ is relatively large (0.322), it is statistically insignificant.

Specification (3) expands the sample to all 4-digit industries, which includes now industries that were either not containerizable or only of limited containerizability using the 1968 classification. Comparing the estimates in (3) with the estimates in (2) reveals that most coefficients remain quite stable. The cumulative average treatment effect of *fullcont* drops from 790% to 692% and the continued statistically insignificant and small size (-0.050) of the coefficient of $\Delta fullcont_{ij,t+1}$ suggests again a causal interpretation. The difference between the cumulative ATE in (2) and (3) is largely driven by the smaller coefficient on the concurrent effect. However, when we conducted a formal test on the effects of product containerzability, we failed to find any statistically significance. In general, we find these results quite interesting since they can be interpreted that container technology did not only increase trade in intermediate goods (autoparts) but also had complementary effects on trade in goods that are not necessarily containerizable (automobiles).

Panel B in Table 2 considers the same specifications from Panel A, but applies them to the port containerization variable (4). Because of the similarity in patterns in Panel A, we only report the coefficients on the *portcont* variables. A striking feature of the estimates in Panel B is that the magnitude of the coefficient on the concurrent and lagged coefficients of *portcont* are less than half the size of the coefficients on *fullcont*. Comparing the benchmark specifications (1) in Panel A and B reveals that the cumulative average treatment effect now drops from 790% to 292%. This suggests an important role of intermodality. Interestingly, specification (2) suggests that the ignorance of railway containerization leads to an economically and statistically significant pre-treatment effect, as the coefficient on $\Delta portcont_{ij,t+1}$ amounts now to 0.217 compared to the estimate of 0.0454 on $\Delta fullcont_{ij,t+1}$ in Panel A. The statistical significance of the pre-treatment variable can be explained by *portcont* attributing a later entrance into the container age for some countries in our sample than the more accurate measure *fullcont*. Similarly to what we found in Panel A, expanding the sample to all industries in specification (3) results only in small changes of the coefficients. The accumulated ATE drops from 319% to 311% and the coefficient on the pre-treatment variable remains statistically significant, but drops from 0.217 to 0.169.

Specifications (4) and (5) give the results on the more balanced panel. This reduces the number of products from 413 to 333 for containerizable products and from 591 to 485 for all products. The results are quite robust and even slightly increases the cumulative average treatment effects in all specifications. In Panel B, the coefficient on the pre-treatment variable reduces its statistical significance in specification (4) and becomes statistically insignificant in specification (5).

Table 3: First differenced panel estimates for world trade (with country-time and product-time fixed effects)

	Full Sample				More Balanced Sample			
	All countries		excl North-North		All countries		excl North-North	
	(1) Containerizable	(2) All industries	(3) Containerizable	(4) All industries	(5) Containerizable	(6) All industries	(7) Containerizable	(8) All industri
Panel A: Full Containerization								
$\Delta fullcont_{ij,t}$	1.200***	1.244***	1.139***	1.174***	1.306***	1.344***	1.238***	1.268***
	(0.0152)	(0.0135)	(0.0174)	(0.0156)	(0.0160)	(0.0142)	(0.0184)	(0.0164)
$\Delta fullcont_{ij,t-1}$	0.665***	0.653***	0.578***	0.551***	0.733***	0.715***	0.639***	0.608***
	(0.0152)	(0.0135)	(0.0179)	(0.0160)	(0.0158)	(0.0140)	(0.0187)	(0.0166)
$\Delta fullcont_{ij,t-2}$	0.230***	0.236****	0.059***	0.040*	0.269***	0.273***	0.093***	0.074***
	(0.0144)	(0.0128)	(0.0179)	(0.0159)	(0.0147)	(0.0130)	(0.0184)	(0.0164)
$\Delta fullcont_{ij,t-3}$	0.047***	0.041***	-0.196***	-0.224***	0.071***	0.065***	-0.167***	-0.195***
	(0.0134)	(0.0118)	(0.0183)	(0.0163)	(0.0135)	(0.0119)	(0.0184)	(0.0165)
$\Delta fullcont_{ij,t+1}$	0.294***	0.294***	0.257***	0.255***	0.303***	0.305***	0.265***	0.266***
	(0.00934)	(0.00841)	(0.0099)	(0.00894)	(0.0100)	(0.0090)	(0.0107)	(0.0096)
$\Delta fta_{ij,t}$	0.233***	0.237***	0.131***	0.125***	0.238***	0.243***	0.154***	0.152***
	(0.0168)	(0.0151)	(0.0372)	(0.0334)	(0.0176)	(0.0157)	(0.0399)	(0.0356)
$\Delta fta_{ij,t-1}$	0.168***	0.170***	-0.405***	-0.374***	0.160***	0.163***	-0.413***	-0.382***
	(0.0140)	(0.0125)	(0.0461)	(0.0412)	(0.0146)	(0.0130)	(0.0485)	(0.0431)
$\Delta fta_{ij,t-2}$	0.038*	0.038*	-0.502***	-0.494***	0.035	0.034*	-0.492***	-0.484***
	(0.0182)	(0.0161)	(0.0746)	(0.0659)	(0.0181)	(0.0161)	(0.0745)	(0.0659)
$\Delta fta_{ij,t-3}$	-0.139***	-0.151***	-0.400***	-0.447***	-0.133***	-0.146***	-0.380***	-0.431***
	(0.0207)	(0.0183)	(0.112)	(0.0973)	(0.0205)	(0.0182)	(0.110)	(0.0966)
$\Delta fta_{ij,t+1}$	0.042*	0.040*	0.255***	0.252***	0.037	0.038*	0.223***	0.224***
	(0.0185)	(0.0167)	(0.0432)	(0.0391)	(0.0196)	(0.0177)	(0.0464)	(0.0418)
$\Delta GATT_{ij,t}$	0.287***	0.314***	0.322***	0.353***	0.302***	0.333***	0.336***	0.373***
	(0.0136)	(0.0122)	(0.0148)	(0.0134)	(0.0145)	(0.0130)	(0.0158)	(0.0142)
$\Delta GATT_{ij,t-1}$	0.133***	0.135***	0.200***	0.201***	0.112***	0.121***	0.183***	0.190***
	(0.0125)	(0.0113)	(0.0139)	(0.0126)	(0.0133)	(0.0119)	(0.0148)	(0.0133)
$\Delta GATT_{ij,t-2}$	-0.029*	-0.010	-0.001	0.0135	-0.018	0.000	0.009	0.024
	(0.0132)	(0.0119)	(0.0151)	(0.0136)	(0.0140)	(0.0125)	(0.0160)	(0.0143)
$\Delta GATT_{ij,t-3}$	-0.077***	-0.067***	-0.096***	-0.094***	-0.067***	-0.055***	-0.088***	-0.084***
	(0.0134)	(0.0121)	(0.0167)	(0.0150)	(0.0142)	(0.0127)	(0.0176)	(0.0158)
$\Delta GATT_{ij,t+1}$	0.045**	0.052***	0.064***	0.073***	0.054***	0.064***	0.077***	0.089***
	(0.0141)	(0.0127)	(0.0148)	(0.0134)	(0.0149)	(0.0134)	(0.0157)	(0.0141)
Obs	930056	1188748	786285	999205	804758	1044374	672028	867932
Countries	157	157	135	135	157	157	135	135
No. Products	673	908	673	908	345	504	341	494
R^2	0.116	0.108	0.117	0.110	0.116	0.108	0.116	0.109
FE	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt
Total ATE^a	357%	370%	279%	281%	415%	425%	329%	329%
Panel B: Port Containerization								
$\Delta portcont_{ij,t}$	0.754***	0.805***	0.701***	0.738***	0.839***	0.888***	0.779***	0.815***
	(0.0130)	(0.0117)	(0.0153)	(0.0139)	(0.0138)	(0.0124)	(0.0164)	(0.0149)
$\Delta portcont_{ij,t-1}$	0.274***	0.275***	0.159***	0.140***	0.332***	0.331***	0.208***	0.188***
	(0.0134)	(0.0121)	(0.0164)	(0.0149)	(0.0140)	(0.0126)	(0.0174)	(0.0157)
$\Delta portcont_{ij,t-2}$	-0.044***	-0.048***	-0.337***	-0.376***	-0.0201	-0.0223	-0.316***	-0.351***
	(0.0131)	(0.0117)	(0.0174)	(0.0157)	(0.0135)	(0.0120)	(0.0180)	(0.0163)
$\Delta portcont_{ij,t-3}$	-0.205***	-0.221***	-0.658***	-0.709***	-0.190***	-0.205***	-0.637***	-0.686***
	(0.0133)	(0.0118)	(0.0194)	(0.0174)	(0.0134)	(0.0119)	(0.0197)	(0.0177)
$\Delta portcont_{ij,t+1}$	0.228***	0.226***	0.212***	0.206***	0.235***	0.237***	0.218***	0.217***
	(0.0089)	(0.0080)	(0.0096)	(0.0086)	(0.0096)	(0.0087)	(0.0104)	(0.0093)
3-lags GATT & fta	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1st lead GATT & fta	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs	938702	1200017	794931	1010474	811282	1053255	678530	876785
Countries	157	157	135	135	157	157	135	135
No. Products	673	908	673	908	345	504	341	494
R^2	0.113	0.105	0.115	0.108	0.113	0.104	0.114	0.107
FE	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt	it,jt,kt
Total ATE^a	121%	131%	42%	42%	153%	163%	67%	67%

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
[a] Total ATE is the sum of statistically significant container estimates.

Table 3 expands the analysis to the world sample of 157 countries; columns (1)-(4) consider the full sample and columns (5)-(8) the more balanced sample. On the country dimension we consider the full world sample and world trade, excluding North-North (i.e. North-South and South-South). The results in column (1) and (2) indicate that the cumulative average treatment effects are cut my half in Panel A and by almost a third in Panel B. A comparison of the lagged variables suggest that the differences lie in the dynamic effects. Compare for example, column (3) in Table 2 with columns (2) and (4) in Table 3. The concurrent effects of *fullcont* are quite similar and the concurrent effect of *portcont* are even larger in Table 3 than in Table 2. However, while containerization has still a large effect up to 20 years following its introduction in North-North trade, it drops dramatically after five to ten years in trade that is not North-North. This is suggestive of what might be called container-induced diversion of trading activities towards North-

North trade. However, a formal analysis of this conjecture is beyond the scope of this paper.

The presence of a statistically significant pre-treatment effects suggest anticipation effects of containerization when involving developing economies, which in general later adopters of containerization. Interestingly we find now also pre-treatment effects of the GATT. Because of economically and statistically significant pre-treatment effects, our findings in Table 3 suggest strong correlations between containerization and international, but can't be interpreted as causal.

4. Conclusion

International trade is a key dimension of globalization and globalization plays a central for economic development and economic growth. But what are the drivers of international trade and globalization? Business experts and historians who have studied or made a living from the shipment of goods across international borders have long conjectured that "the shipping container made the world smaller and the world economy bigger" (Levinson's (2006) subtitle). In his recent world history of technology, Daniel Headrick (2009, p.146) discusses containerization as the major 20th century technological change that "…has propelled the globalization of the world economy". To the best of our knowledge, we are the first attempt to examine these claims in a rigorous manner. Our findings suggest indeed large effects of containerization, for world trade and North-North trade. For the industrial world, we provide causal evidence for containerization to be a large driver of 20th century globalization.

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Appendix

Appendix Table 1: Variables and Data Sources

Variables	Data Sources
Trade Flows	Feenstra et al. (2005)
Container variables	Containerisation International Yearbooks (several years)
Policy variables	CEPII

Appendix Table 2: Correlations between variables

	North-North			
	$portcont_{ij}$	$fullcont_{ij}$	rta	bothgatt
$portcont_{ij}$	1			
$fullcont_{ij}$	0.7155	1		
rta	0.106	0.2604	1	
bothgatt	0.2369	0.331	0.1186	1
	Entire sample			
	$portcont_{ij}$	$fullcont_{ij}$	rta	bothgatt
$portcont_{ij}$	1			
$fullcont_{ij}$	0.8526	1		
rta	0.1288	0.1993	1	
bothgatt	0.1986	0.278	0.2292	1

Appendix Table 3: Countries in the sample

Panel A: Countries that containerize by port or rail 1966-1983 (122 countries)

1966	India(R)	Netherlands(P)*	UK(P)(R)*	USA(P)*	West Germany(P)*
1968	Australia(P)*	Austria(R)*	Belgium(P)*	Canada(P)*	Denmark(P)*
	East Germany(R)	France(P)*	Hungary(R)	Ireland(R)*	Italy(P)*
	Spain(R)*	Sweden(R)*	Switzerland(R)*	Taiwan(P)	
1969	Finland(P)*	Yugoslavia(R)	Japan(P)*	Norway(R)*	Portugal(P)*
1970	Hong Kong(P)	USSR(R)	Greece(P)*	Israel(P)	Romania(R)
	Singapore(P)				
1971	Cote D'Ivoire(P)	New Zealand(P)*	Philippines(P)	Poland(P)	Trinidad(P)
1972	Bulgaria(R)	Czechoslovakia(R)			
1973	Bahamas(P)	Brazil(P)	Iceland(P)*	Jamaica(P)	Malaysia(P)
1974	Cameroon(P)	Chile(P)	Colombia(R)	Nigeria(P)	Panama(R)
	South Africa(P)				
1975	Barbados(P)	Honduras(P)	Indonesia(P)	Korea Rep(P)	Peru(P)
	Thailand(P)				
1976	Argentina(P)	Benin(P)	Kenya(P)	Mexico(P)	N. Caledonia(P)
	Saudi Arabia(P)	UAE(P)			
1977	Bahrain(P)	Cyprus(P)	Ghana(P)	Iran(P)	Jordan(P)
	Kuwait(P)	Lebanon(P)	Morocco(P)		
1978	Ecuador(P)	Egypt(P)	Gibraltar(P)	Haiti(P)	Iraq(P)
	Mozambique(P)	Oman(P)	Papua N. Guinea(P)	Samoa(P)	Sierra Leone(P)
	St. Kitts Nevis(P)	Tanzania(P)			
1979	Algeria(P)	Angola(P)	China(P)	Congo(P)	Djibouti(P)
	El Salvador(P)	Mauritius(P)	Neth.Antilles(P)	Nicaragua(P)	Pakistan(P)
	Qatar(P)	Sri Lanka(P)	Syria(P)		
1980	Guatemala(P)	Liberia(P)	Libya(P)	Madagascar(P)	Sudan(P)
	Uruguay(P)				
1981	Brunei/Bhutan(P)	Bangladesh(P)	Belize(P)	Costa Rica(P)	Dem.Rep.Congo(P)
	Dominican Rep(P)	Fiji(P)	Guadeloupe(P)	Seychelles(P)	Togo(P)
	Tunisia(P)	Turkey(P)	Venezuela(P)		
1982	Gambia(P)	Kiribati(P)	Mauritania(P)	St.Helena(P)	
1983	Bermuda(P)	Ethiopia(P)	Guinea(P)	Malta(P)	Myanmar(P)

(P) denotes that the country containerized by port first.
(R) denotes that the country containerized by rail first.
(*) denotes that the country is in the North-North sample.

Panel B: Countries that do not containerize by port or rail 1966-1983 (35 countries)

Afghanistan	Chad	Greenland	Mongolia	Senegal
Albania	Cuba	GuineaBissau	Nepal	Somalia
Bolivia	Eq. Guinea	Guyana	Niger	Suriname
Burkina Faso	Falkland Islands	Laos	North Korea	Uganda
Burundi	French Guiana	Macao	Paraguay	Viet Nam
Cambodia	French Overseas	Malawi	Rwanda	Zambia
Cen. African Rep	Gabon	Mali	St. Pierre Miquelon	Zimbabwe

Appendix Table 4: List of industries

Panel A: Containerizable products at the 4-digit SITC level as of 1968 (688 products)

Code	Good Description (number of underlying 4-digit products)
35	Fish, dried, salted or in brine smoked fish (1)
37	Fish, crustaceans and molluscs, prepared or preserved (3)
42	Rice (3)
46	Meal and flour of wheat and flour of meslin (1)
47	Other cereal meals and flours (1)
48	Cereal preparations & preparations of flour of fruits or vegetables (6)
56	Vegetables, roots & tubers, prepared/preserved, n.e.s. (4)
58	Fruit, preserved, and fruit preparations (1)
61	Sugar and honey (6)
62	Sugar confectionery and other sugar preparations (1)
71	Coffee and coffee substitutes (3)
72	Cocoa (4)
73	Chocolate & other food preptions containing cocoa (1)
74	Tea and mate (3)
75	Spices (3)
81	Feed.stuff for animals (not including unmilled cereals) (6)
91	Margarine and shortening (3)
98	Edible products and preparations n.e.s. (1)
111	Non alcoholic beverages, n.e.s. (1)
112	Alcoholic beverages (5)
121	Tobacco, unmanufactured; tobacco refuse (4)
122	Tobacco manufactured (4)
211	Hides and skins (except furskins), raw (7)
212	Furskins, raw (including astrakhan, caracul, etc.) (1)
222	Oil seeds and oleaginous fruit (excluding flours and meals) (7)
223	Oils seeds and oleaginous fruit, whole or broken (including flours and meals) (7)
23	Crude rubber (including synthetic and reclaimed) (5)
244	Cork, natural, raw & waste (including in blocks/sheets) (1)
25	Pulp and waste paper (7)
26	Textile fibres (except wool tops) and their wastes (30)
277	Natural abrasives, n.e.s (including industrial diamonds) (3)
291	Crude animal materials, n.e.s. (3)
411	Animal oils and fats (3)
423	Fixed vegetable oils, soft, crude, refined/purified (7)
424	Other fixed vegetable oils, fluid or solid, crude (7)
431	Animal & vegetable oils and fats, processed & waxes (5)
53	Dyeing, tanning and colouring materials (11)
54	Medicinal and pharmaceutical products (8)
55	Essential oils & perfume materials; toilet polishing and cleansing preparations (9)
58	Artificial resins, plastic materials, cellulose esters and ethers (29)
59	Chemical materials and products, n.e.s. (13)
61	Leather, leather manufactures, n.e.s. and dressed furskins (13)
62	Rubber manufactures, n.e.s. (13)
63	Cork and wood manufactures (excluding furniture) (13)
64	Paper, paperboard, articles of paper, paper-pulp/board (15)
65	Textile yarn, fabrics, made-up articles, related products (61)
664	Glass (10)
665	Glassware (5)
666	Pottery (1)
667	Pearls, precious & semi-prec.stones, unwork./worked (5)
673	Iron and steel bars, rods, angles, shapes & sections (5)
674	Universals, plates and sheets, of iron or steel (8)
675	Hoop & strip, of iron/steel, hot-rolled/cold-rolled (1)
677	Iron/steel wire, wheth/not coated, but not insulated (1)
678	Tubes, pipes and fittings, of iron or steel (6)
679	Iron & steel castings, forgings & stampings; rough (1)
681	Silver, platinum & oth.metals of the platinum group (3)

682	Copper (3)
683	Nickel (3)
684	Aluminium (3)
685	Lead (3)
686	Zinc (3)
687	Tin (3)
689	Miscell.non-ferrous base metals employ.in metallgy (3)
692	Metal containers for storage and transport (3)
693	Wire products and fencing grills (4)
694	Nails, screws, nuts, bolts etc.of iron, steel, copper (1)
695	Tools for use in hand or in machines (5)
696	Cutlery (2)
697	Household equipment of base metal, n.e.s. (5)
699	Manufactures of base metal, n.e.s. (10)
71	Power generating machinery and equipment (26)
723	Civil engineering and contractors plant and parts (4)
724	Textile & leather machinery and parts (7)
725	Paper and pulp mill mach., mach for manuf.of paper (4)
726	Printing and bookbinding mach.and parts (6)
727	Food processing machines and parts (2)
728	Mach. & equipment specialized for particular ind. (5)
73	Metalworking machinery (11)
745	Other non-electrical mach.tools, apparatus & parts (2)
749	Non-electric parts and accessories of machines (5)
75	Office machines & automatic data processing equipment (15)
76	Telecommunications & sound recording apparatus (16)
77	Electrical machinery, apparatus & appliances n.e.s. (31)
8	Miscellaneous manufactured articles (114)

Panel B: non-containerizable products at the 4-digit SITC level as of 1968 (275 products)

Code	Good Description (number of underlying 4-digit products)
001	Live animals chiefly for food (7)
01	Meat and meat preparations (15)
02	Dairy products and birds' eggs (9)
034	Fish, fresh (live or dead), chilled or frozen (5)
036	Crustaceans and molluscs, fresh, chilled, frozen etc. (1)
041	Wheat (including spelt) and meslin, unmilled (3)
043	Barley, unmilled (1)
044	Maize, unmilled (1)
045	Cereals, unmilled (no wheat, rice, barley or maize) (4)
054	Vegetables, fresh, chilled, frozen/preserved; roots, tubers (7)
057	Fruit & nuts (not including oil nuts), fresh or dried (9)
245	Fuel wood (excluding wood waste) and wood charcoal (1)
247	Other wood in the rough or roughly squared (4)
248	Wood, simply worked, and railway sleepers of wood (4)
271	Fertilizers, crude (5)
273	Stone, sand and gravel (5)
274	Sulphur and unroasted iron pyrites (3)
278	Other crude minerals (7)
281	Iron ore and concentrates (4)
282	Waste and scrap metal of iron or steel (2)
287	Ores and concentrates of base metals, n.e.s. (9)
288	Non-ferrous base metal waste and scrap, n.e.s. (3)

289	Ores & concentrates of precious metals; waste, scrap (1)
292	Crude vegetable materials, n.e.s. (8)
3	Mineral fuels, lubricants and related materials (25)
51	Organic chemicals (29)
52	Inorganic chemicals (14)
56	Fertilizers, manufactured (5)
57	Explosives and pyrotechnic products (5)
661	Lime, cement, and fabricated construction materials (5)
662	Clay construct.materials and refractory constr.mater (3)
663	Mineral manufactures, n.e.s (8)
671	Pig iron, spiegeleisen, sponge iron, iron or steel (4)
672	Ingots and other primary forms, of iron or steel (5)
676	Rails and railway track construction material (1)
691	Structures & parts of struc.; iron, steel, aluminium (4)
721	Agricultural machinery and parts (5)
722	Tractors fitted or not with power take-offs, etc. (3)
781	Passenger motor cars, for transport of pass., goods (1)
782	Motor vehicles for transport of goods and materials (3)
783	Road motor vehicles, n.e.s. (3)
785	Motorcycles, motor scooters, invalid carriages (4)
786	Trailers and other vehicles, not motorized (4)
791	Railway vehicles and associated equipment (7)
792	Aircraft and associated equipment and parts (7)
793	Ships, boats and floating structures (5)
9	Commodities and transactions not elsewhere classified (7)