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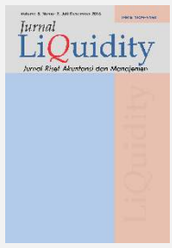

GEOGRAPHICAL CONDITION AND PORT DEVELOPMENT (KONDISI GEOGRAFIS DAN PEMBANGUNAN PELABUHAN)

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Abstract

The first-time purposely build container ships introduced in 1967 with a draft of 9 meters, and now, newer container ship drafts can reach 16 meters and more. The development of the container ship dimension is rapid. Ports respond to these changes and keep up with the more significant size and a deeper draft of the new container ship design. Ports are developing their infrastructure from installing gantry cranes to dredge their seafloor. This research reviews that phenomenon and studied how ports adapt to the changing container ship dimension, especially for Post Panamax container ships built for efficiency. To do that, we use an exogenous variable of ports' depth from 1972 to 1985 before the ports knew that they would need deeper depth to accommodate such ships. We find that ports with actual depth more or equal to 13.716 meters is significantly affected port to accommodate Post Panamax container ship in this present time. The scope of this research is to show how a port responds to the change of the dimension of a container ship. Nevertheless, this research can be a steppingstone to measure the causality of trade that never has been done correctly before by introducing an exogenous variable that is strong, which port's depth regarding the Post Panamax container ship draft.

Kata Kunci: Regression Discontinuity, Containerization, Port Development, Exogenous Variation, Causal Inference

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PENDAHULUAN

As the world becomes more connected than before, there are four cornerstones of globalization: telecommunications, trade liberalization, international standardization, and transportation Kumar & Hoffmann (2002). Globalization makes the movements of raw materials and components unimaginable, and the most efficient way to move tons of goods to other places is maritime transport. Consequently, cargo ships carry over 90 per cent of international trade.

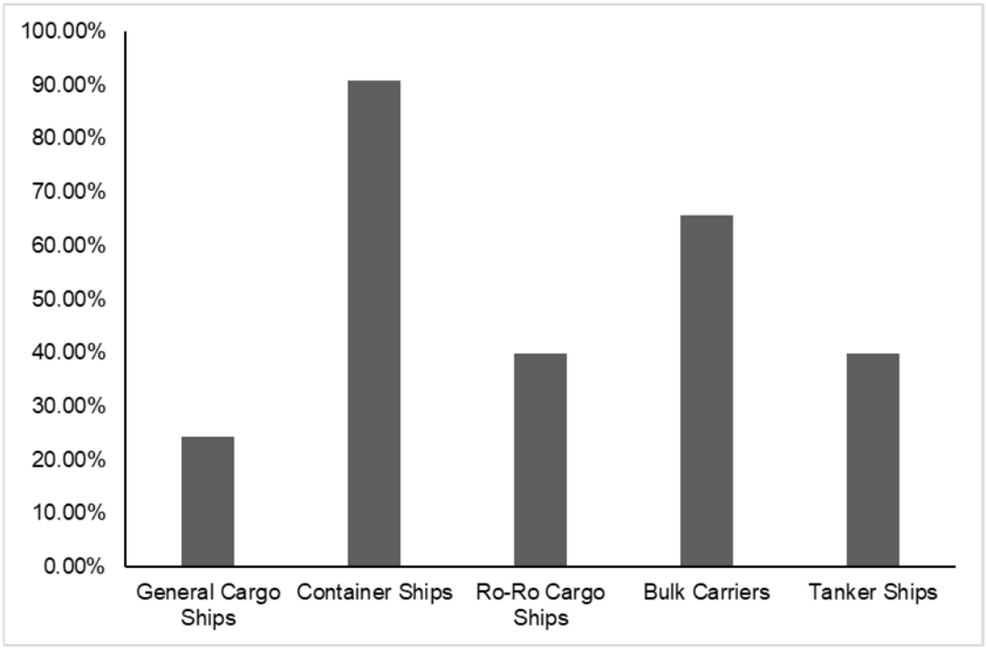
Ancient civilizations used the ship to carry their cargo from the dawn of history; Egyptians built pyramids by moving 5.5 million limestones weight 8,000 tons each from a quarry 800 km away using ship via nile river even before men invented the wheel. In 6 Before Common Era (BCE), Phoenicians' boats were trading material, tools, and finished goods between nations in the Mediterranean. Moreover, in olden times, ships are powered by winds. When the industrial revolution comes, steamship is sprung up; hence, the sea transportation cost is significantly reducing and becoming more efficient (Pascali, 2017).

In contemporary times, we have a plethora of ships to carry all kinds of goods from liquid natural resources using tanker ships, metal and raw materials using bulk carrier ships, or even finished goods using container ships. Furthermore, to make shipping more efficient, all of those ships are on a grander scale.

There are specialized ships to carry different goods, based on their cargo; there, are different ship types: a) General Cargo/Break Bulk Ship, which designed to carry general cargo that requires individual loading, usually has built-in cranes; b) Container Ship, which achieves intermodal transport between sea and land, should be a standardized container, and Container Ship designed to answer the need. With a standardized box, between ship will easily move goods to land transport (train or truck); c) Refrigerated Cargo/Reefer Ship, which can keep cargo temperature low, best suited to carry food and perishable goods; d) Bulk Carrier Ship, which carries solid bulk load such as sand and grains; e) Tanker Ship, there are few types of tanker ship depending on their cargo.

such as (1) Crude Carrier Ship, which usually carries crude oil; (2) Chemical, and Product Carrier Ship, which carries other liquid chemicals in bulk; and (3) Liquefied Gas Carriers, carries Liquefied Petroleum Gas (LPG) or Liquefied natural Gas (LNG); f) Ro-Ro Ship, which is an abbreviation for Roll On-Roll Off, this ship has a ramp, so it is best suited to transport wheeled vehicles; and g) Livestock Ship has feeding zones so it can carry the animal.

Out of all those different types of ships, the most prominent one is the Container Ship. In 2017, it carried goods value for USD12 trillion, which accounted for 60 per cent of ocean trade.



Source: Equasis, 2006, 2011.

Figure 1. World Ship Cargo Volume Change between 2005 and 2010 by Types

By comparing data of different ships type gross tonnage in 2005 to 2010 (Figure 1), it illustrates that Container Ships have the highest increase (90.86 per cent), followed by Bulk Carriers (65.71 per cent). Even though Container Ship is almost 50 years since introduced, there is still a high increase in the container ship fleet, which shows container shipping still has potential growth in the future.

Before the dawn of containerization, there were numerous works to ship goods, from packaging in a firm to use land transport and repackaging in the harbours to suitably transported using a ship. Although shipping cost is cheaper than other modes, repackaging and sorting of transported goods generate extra cost in shipping goods.

In the mid-1950s, with a standardized box called Twenty-foot Equivalent Unit (TEU), sea trade entering the era of containership. This box purpose is to simplify the intermodal transportation method. Therefore, goods are effortlessly moving from land transport to a container ship.

From 1956 to 1981, there was an increase in international trade growth for more than 1,000 per cent because of containerization (Bernhofen et al., 2016). Besides, there is also substantial growth of the local economy and employment in cities around container ports (Brooks et al., 2018). These results show that simple packaging is a good idea; thus, many ports adopted and benefited.

Evolution of Container Ships

Nowadays, many ports that accommodate Container Ship have very deep-water. However, the term "deep water" port is different from time to time, depending on the ship's needs. Before the Container Ship introduce in 1956, a deep port is a port that has a depth of more than 30 feet (9.144 m) (Brooks et al., 2018). Therefore, many ports with 30 feet depth have Container Terminal.

There are six sea trade bottlenecks worldwide that restricted the ship's draft that crosses: Panama, Gibraltar, Suez, Hormuz, Malacca, and Oresund. Out of these six, there are two human-made routes, which are Panama and Suez. Moreover, the Panama Canal and Suez Canal have the shallowest depth out of 6; also, they are unique because they are under a country's jurisdiction. Therefore, it will be easier to lift those dimensions or draft dimensions if the countries needed to.

Unlike Suez, Panama cannot be dredge because it uses a canal system to lift the ships from the Atlantic Ocean to the Pacific Ocean, vice versa. Due to that, Panama Canal has the same restriction for 100 years that is 100 feets(33.528 meters) beam, 1,000 feets (304.800 meters) length, and 40 feets (12.902 meters) draft. This restriction applies until the opening of the new Panama Canal locks that opened in 2016.

The shipping industry builds a more significant size container ship as an effort to reduce transportation cost. At first, the Panama Canal Lock dimension restricted container ship size. In 1972, NYK Kurama Maru was the first Panamax ship. Panamax ship is a container ship that reached the maximum Panama Canal old lock dimensions.

In 1970, after the launch of NYK Kurama Maru, Panamax became standard for container shipping. From 1970s to the late 1980s, many Container Ships have similar dimensions to NYK Kurama Maru. Although this design is popular because of its versatility to cross one of the most restricted shortcuts globally, it has an efficiency problem.

Container ship design that can cross Panama Canal causes inefficiency. This inefficiency occurs when the maximum beam reaches 33.528 meters, ship designer's only option to increase the ship carrying capacity is to increase its length. Consequently, the container ship's shaft increase to length ratio will reduce water resistance, manoeuvrability, and propulsion power, thus increasing the container ship (Bertram & Schneekluth, 1998).

To reduce operational cost, ship maker has to turn into beyond Panama Canal restrictions. In 1988, the first Post Panamax container ship, christened as APL President Truman, launched in 1988 and became a new standard in the early 1990s. Not restricted by Panama Canal dimension, ship architects can rebalance the relation between capacity and ship dimension. Container ships can achieve better efficiency in construction and operational cost by reducing the length to beam ratio (Martin et al., 2015). Furthermore, the economies of scale in Container Ship increase significantly (Rodrigue et al., 2016).

Panamax ship was built based on restriction of Panama Canal; nevertheless, Post Panamax ship is based on the efficiency of the design and finding the best ratio of ship length and beam. Before the New Panama Canal lock, are two types of Post Panamax ship, first is the Post Panamax that was standard in the 1990s with a capacity of 4,000 to 5,000 TEU and the dimension of length 935 feet, beam 131 feet, and draft 43

feet. Second is Post Panamax Plus with a capacity of 6,000 to 8,000 TEU and the dimensions of length 984 feet, beam 141 feet, and draft 49 feet (Florida Department of Transportation, 2018).

Ports will need to have at least 45 feet of depth to accommodate Post Panamax container ships, and not many ports reach that depth especially in container terminal. This draft restriction compels ports to dredge their seafloor (Rodrigue et al., 2016). In The USA, the Post Panamax standard is redefining "Deep Water" ports term from 30 feet to 45 feet or port that can accommodate fully laden Post Panamax Ship.

The rise of the new Post Panamax standard is unstoppable, and Panama Canal traffic is declining; thus, Panama Canal must adapt. In 2006, there is a referendum in Panama to choose between expanding the Panama Canal or not. Resulting the decision to expand the Panama Canal. The Panama Canal expanding project started in 2008.

The first time the New Panamax ship dimensions mentioned in 2006. Panama Canal Authority (ACP) officialized the name and the specifications in 2009, which describe that the New Panamax Ship will have a maximum length of 365.76 meters, beam of 49 meters, and draft of 15.24 meters. New Panamax container ships dimension is larger than Post Panamax II container ships and gives way to a new standard.

Be wary that the Panama Canal uses a human-made lake to cross between the Atlantic and the Pacific Ocean, and it comes with some problem. First, water on the lake is tropical freshwater, so it would not lift as much as saltwater, hence, making draft restriction lesser. For instance, full laden Panamax Ship has a different draft of 0.3 meters deeper in Gatun Lake than in the open sea. Secondly, because Gatun Lake is human-made, the lake is always water-deficient, and making the draft is lesser than the description. To illustrate, on 25 July 2019, 3 years after it was open, the maximum draft of a ship that crosses the canal is 14.63 meters tropical freshwater.

After the first purposely built containership in 1967, the first notable changes need more than ten years, = the "deep water" port depth of the 1950s. After the first changes, the standard in container ship changes, and a new generation that has a deeper draft rise in every decade.

Table 1. Change in Containership Draft

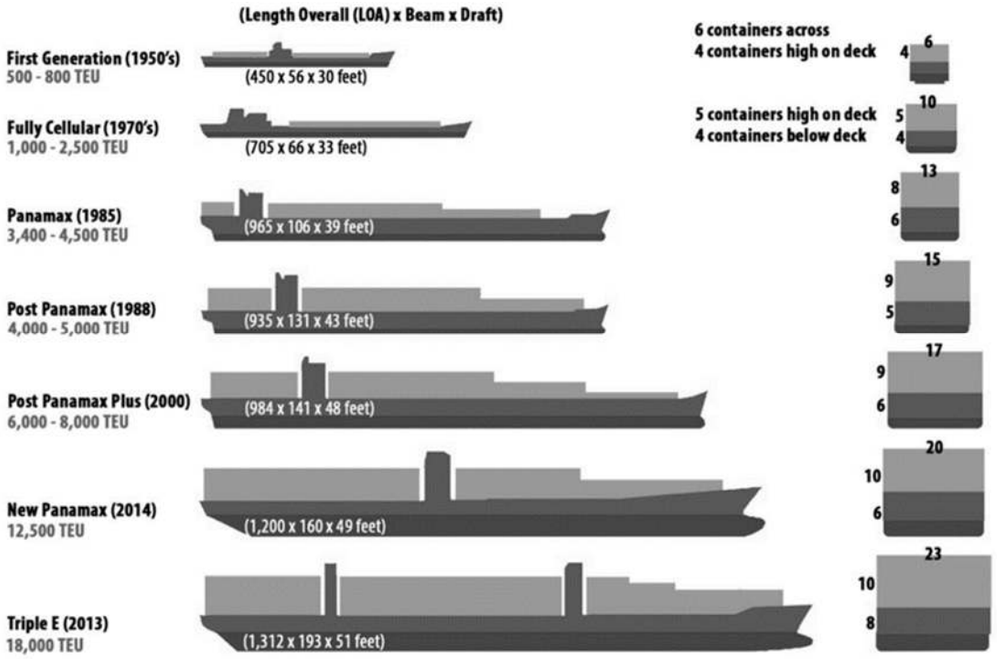
Year	Milestones	Capacity (TEU)	Max Draft (meters)
1967	First purposely built container ship	700	9
1972	First Panamax dimensions (NYK Kurama Maru)	2,288	12
1988	First Post Panamax (APL President Truman)	4,300	12.5
2000	First Post-Panamax II	8,500	14.5
2006	Panama Canal Expansion referendum (New Panamax dimension introduction)	12,500	15.2
2006	First Very Large Container Ship (Emma Maersk)	14,770	16
2013	First Ultra Large Container Ship (Maersk Triple E Class)	18,340	16

Source: Compile from Evangelos (2006)

Shipwright or shipbuilder industries and ports authority are two entities that have a mutual symbiotic relationship. Simultaneously, shipwrights have imagination

and law of physics as limitation, ports authority limited by the geographical condition of its surrounding. This scenario is plausible in the Container Ship industry, where shipwrights have a rapid development in the Container Ship dimension for the last seven decades.

Figure 2 shows that the first-generation container ship that can carry only around 800 TEU. Moreover, these first-generation ships initially not built to carry containers, but a repurpose from tankers. Not after around 20 years, in 1967, a specialized ship was built to carry container. After the ship's launch, the development of container ships starts to incline. Not only their dimensions are getting bigger, but also their draft is getting deeper. Notable milestones are when the dimension reaches the maximum allowed size for Panama Canal. At this point, shipbuilders start to categorize ships based on their dimensions and which route that the ship can sail. After the launch of the Panamax container ship, the ship size and draft are changing radically. Ports are responding by dredging and building infrastructure for the new ship dimension.



Source: Florida Department of Transportation, 2018.

Figure 2. Containership Evolution from 1950 to 201

Trickle-down effect of mega ships

Container ship sets a new milestone in 2006 with the introduction of Emma Maersk. It is the first Very Large Container Ship with loading capacity of 14,770 TEU. This event makes way of another type of container ships, which is Ultra Large Container Ship that introduced in 2013. Both types of container ships are called mega ships.

Mega ships are significantly bigger than the previous type of container ship (Post Panamax II) and can haul an unimaginable number of containers. Mega ships need more time to unload than its predecessor, hence, the big ports are busy to accommodate those ships and have less time to receive Post Panamax II container ships. Therefore, Post Panamax II container ship trickle down to other trade routes (ITF, 2015). The trickle-down-effect of mega ships makes smaller port more viable and efficient if they can accommodate the previous standard of container ships.

Port development and the effect of introducing new containership dimension

To investigate how the container ship dimension change affects port development, we implement causal inference using Regression Discontinuity Design (RDD). To quantify using RDD, we identify the port's original depth as an exogenous variable that can be used for a running variable.

Many kinds of research are focusing on the effect of implementing containerization in trade. However, there is no article that investigating how the geographical condition can affect the port decision to accommodate new ship generation. Geographic condition is random by nature, so it can be a suitable identification method to tackle confounders that will exist when calculating trade effect. The geographic condition is not an excellent Instrumental Variable (IV) because geographical advantage will directly affect the outcome. Hence, it is violating the exogeneity assumption for the instrumental variable. Due to this, the method used in the research is RDD instead of IV.

Because of the rapid change in generations of Container Ships, means that Port has to develop fast to adapt to the fast-changing of ship design. Moreover, ports that already have a suitable depth to accommodate newer ship draft will have the advantage to develop deeper container ship terminal. Furthermore, there is a trickle-down-effect of mega ships that revitalize trades routes. This onditions lead to the research question: Did the original depth of port before the introduction of Post Panamax II Container Ship dimension affect port to develop accommodation for the Post Panamax II Container Ship dimension? This research also has the potential to quantify economic growth, trade, income, and other socioeconomic variables. Nevertheless, because of data limitation, this article only covers actual depth that affects port accommodation.

METHOD

The scope of this research is to find the effect of natural depth on the acceptance of the Post Panamax container ship. Nevertheless, it has research potential to quantify trade effect to socioeconomic variables.

Many studies tried to find the effect of container trade on the economy. Frankel & Romer (1999) is one of the first papers that uses causal effect to quantify trade. The authors use exogenous variables as IV, such as the distance of two countries and population in the first stage of regression. The distance of two countries and population as exogenous variables can directly or indirectly affect economic growth from a channel other than trade makes them violated exclusion restriction. Alcala & Ciccone (2004) also find that trade has a positive effect on productivity. This claim is

based on the IV estimation they estimate. Unfortunately, their IV is still using geographical IV based on Frankel and Romer (1999), which violates exclusion restriction.

Irwin & Terviö (2002) find that countries' trade positively affects growth by using IV to control the trade endogeneity. The IV they used is the distance to another trade partner. While the IV is indeed a geographical condition, the exclusion restriction is not fulfilled. The exclusion restriction violation is because distance can affect growth not only from trade but also through bilateral cooperation. Henceforth, the closer the country to other countries is the bigger chance that they have bilateral or multilateral cooperation that can benefit both parties.

Awokuse (2003) using Granger-causality to investigate the direction of exports to GDP and finds that export-led growth hypothesis in the short and long run. The writer is using Granger-causality to detect if a variable following another variable through the lags. This method does not conform to the causality of trade.

Using many challenging to obtain data, Clark et al. (2004) calculate the impact of transport cost to trade. To handle confounders, the researchers using as many control variables as they could. This practice is useful when we know all the confounding variables, but we cannot measure all the variables. Thus, they cannot claim causality by controlling many variables.

Rodrik et al. (2004) replicate the instrumental variable of mortality from the article The Colonial Origins of Comparative Development: An Empirical Investigation (Acemoglu et al., 2001) with more extensive set of observation data. The problem might arise when they do the first stage with mortality rate and geographical location, which can violate exclusion restriction.

Felbermayr (2005) refuted the method used by Frankel & Romer (1999) and proved that using the Generalized Method of Moments (GMM) method is better. Despite the fact that the Instruments used by Frankel & Romer are obsolete because it does not fulfill exclusion restriction, the GMM method also cannot handle the endogeneity problem. Soukiazis & Antunes (2011) also use a similar method. In their research, the writers use the GMM model combine with IV of lagged variables to solve the endogeneity problem. Nevertheless, lagged variables are indeed affected by confounder, and the exogeneity condition is not satisfied.

Taking advantage of the closing of the Suez Canal from 1967-1975, Feyrer (2009) finds the effect of increasing distance to trade and income. Unfortunately, the closing that perceives as a natural phenomenon is not so natural after all, and the canal closed because of the Arab – Israel war. Thus, we cannot compare trade on war and peace situation; this is an unequal comparison between control and treatment.

This article from India Jawaid & Raza (2013) shows causality by using three methods: granger causality analysis, Toda and Yamamoto modified Wald test causality analysis and variance decomposition method. Unfortunately, those methods do not solve the endogeneity problem; thus, the estimation still a correlation relationship.

Lo Turco & Maggioni (2013) quantify causality by combining Difference in Differences (DID) and Propensity Score Matching (PSM) method. The authors find

that the average treatment effect of trade initiation had a positive effect on employment. DID and PSM is indeed causal inference methods; regrettably, using PSM is not advisable because it creates imbalance and bias in estimation (King & Nielsen, 2019).

Bernhofen et al. (2016) research use Difference-in-Differences method to quantify the effect of adopting containerization on trade. Unfortunately, countries that have high trade volume is rich enough to build container ship infrastructures, countries that have a low trade volume will be a late adopter.

Zahonogo (2016) finds that trade openness and growth causality in the long run. However, there is no causality can be proven between trade openness and growth using the Pooled Mean Group. The author can only prove relationship not causality. Consequently, because he is not using causal inference, he could not state that his result impacts trade openness to economic growth.

Coşar & Demir (2018) finds the effect of using a container or regular breakbulk on Firms level. The weakness of this research is the control group and the treatment group are not identical. Furthermore, private firms will always try to be efficient, and they will pick the best way to deliver their product while considering many things, such as distance and the fragility of the product.

Not only using Difference-in-Differences, but Brooks et al. (2018) also use IV estimations to strengthen further the result where the IV use is a binary if the water depth in port proximity is very deep (more than 30 feet/9.1 Meters) in 1953 (before the birth of containerization). Still, the IV cannot handle the endogeneity problem. The problem is that regions with have deep water and calm water are usually prosperous. They will quickly add infrastructure for containerization. Hence, the exogeneity condition is not fulfilled.

Many pieces of research show their weakness in proving causality. Show that causality in trade is hard to prove (Feyrer, 2019). This research uses the Sharp Regression Discontinuity Design (RDD) method to find causality between port development and port depth. In RDD, there will be "local randomness" in the bandwidth area around the cut-off, and the result, by construction, will resolve endogeneity problems.

Type and Data Source

An ideal variable for running variable is the ports' natural depth, but there is a limitation of defining natural depth in the port area. Also, all container terminals in a port are dredge. Due to that reason, as a running variable, we use data of the depth of the container terminal before the launch of the Post Panamax generation container ship.

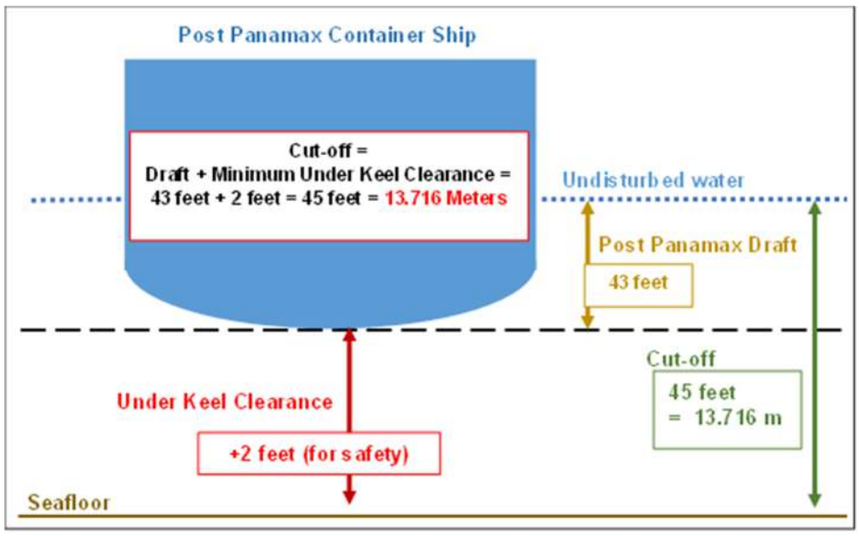
Data used in this research consists of 399 ports that can accommodate container ships from worldwide. For ports' natural depth data, we take container terminal depth taken from Containerisation International Yearbook 1972, 1974-1985. Those are the years before the launch of the first Post-Panamax ship in 1988. The data set does not contain the 1986-1988 edition of the Containerisation International Yearbook to prevent spillover from the knowledge of the Post Panamax ship was in construction so that the port can adapt to them at its launch.

To estimate actual depth, we use container terminal depth data from Containerisation International Yearbooks 1972, 1974-1985. Unfortunately, the early years of the Containerisation International Yearbooks did not contain as many ports as the newer ones. Consequently, we accumulate data from all 13 editions and pick the oldest data. For example, Nantes ports in France depth data is 9 meters in the 1980 edition and 13.5 meters in 1985; hence, we pick data from 1980.

Aside from the actual depth, we also collected the container terminals' current depth to find the outcome variable. Port container terminals current depth data source is from findaport.com and various port authority websites. The data collected by the author in June 2020. The data is reflecting the latest data available.

There are two types of port depth data from Containerisation International Yearbook: container terminal depth and allowable draft. Because of the squat effect, we have to add 2 feet (0.6 m) to the allowable draft to equate those data. 2 feet is a simplified minimum safe distance between port basin floor and ship's deepest underwater hull point.

The outcome variable is binary. The variable is "1" when the current port depth is more than 13.712 meters (the sum of the draft of Post Panamax container ship and simplified UKC) and "0" if the current depth is less than 13.712 meters.



Source: Author analysis based on Helsinki Commission, 2014.

Figure 3. Identifying Cut-off of Post Panamax Container Ship

According to the Florida Department of Transportation (2018), the Post Panamax container ship draft is 43 feet. However, the draft alone cannot be used because the ship will be stuck on the seafloor if the seafloor has the same depth as the ship draft. Consequently, there has to be some space between the ship bottom and the seafloor. This space has to be deep enough to accommodate the ship's movement. When the ship moves, their draft will be slightly deeper than when they stay still.

According to safety regulations, the minimum depth between ship bottom and seafloor can accommodate ship movement in the port area is 2 feet or around 0.6 meters (Helsinki Commission, 2014). It is only 2 feet because a smaller boat tow container ship when entering a port; thus, the speed is slow and the buoyance is small. Also, in port there is not much wave because of the wave breaker. Therefore, to calculate that the cut-off, which is the minimum depth that can accommodate the Post Panamax container ship, we use the Post Panamax container ship (43 feet draft), and we add 2 feet under keel clearance. The sum of the ship's draft and under keel clearance is 45 feet or 13.716 meters.

Model Specification

This article uses sharp RDD methodology where there are three main variables, which are treatment variable (C), outcome variable (Y) and running variable (X). this research model is:

$$Y=\beta C+u \quad \text{..... (1)}$$

$$C=I\{X\geq 13.716\} \quad \text{..... (2)}$$

Where:

Y : Dummy variable, shows "1" if current container terminal depth of the port more than or equal to 13.716 meters (port can accommodate Post Panamax ship) and "0" if otherwise.

C : Dummy variable unit receive treatment or not, "1" if container terminal depth before Post Panamax ship launched more than or equal to 13.716 meters (port accommodate Post Panamax ship) and "0" if otherwise.

X : Running variable, which is ports' actual depth, when it is greater than cut-off, unit get treatment.

This model will use to compare the treatment and control group that is close to the cut-off. In the RDD case, we cannot compare all data on the left side of the cut-off as the treatment group and all data on the right side of the cut off as the control group because it will cause overestimation. The problem is an endogeneity problem where the area that naturally has deeper seafloor might be more advantageous than the area with shallow seafloor.

RESULTS AND ANALYSIS

In this section, we will quantify the RDD model and deliver the analysis. In RDD, we have to do a series of test before we run the RDD. After, we run the RDD, we also check if the results are strong by doing several robustness checks, which recommended in The RDD method.

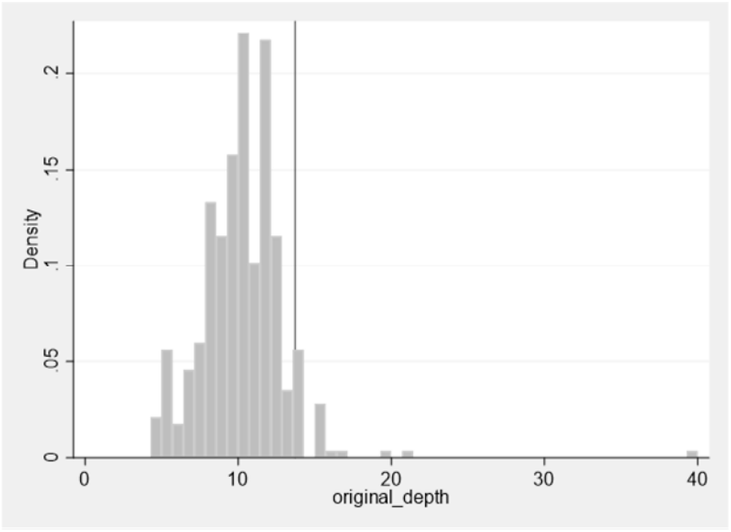
Data Validity Checks

Before quantifying the model, we have to do a test to check the validity of the data. These tests are essential to measuring the reliability of the data so that there is no manipulation from the port to select whether they consciously pick to accommodate the Post Panamax container ship or not. There are two tests that we do, which are the manipulation test and McCrary's test.

1. **Test for Manipulation in Original Port Depth**

First, we check the data distribution on the histogram, as shown in Figure 4. The histogram shows a normal distribution with most ports at 10 meters depth. The distribution indicates that the introduction of container ships in 1967 compel ports to adapt and dredge their container terminals' seafloor to 10 meters. The 10 meters depth is to accommodate newly introduce container ships in 1967 without estimating that they will need a much deeper port in the future. Besides, in an area close to the cut-off of 13.716 meters (black line), we can see a slight drop. This drop can signify the port's tendency to dredge. If the port has a depth just a little less than 13.716 meters, they have incentive to dredge for adopting a newer generation of container ship. To check whether the port chooses to manipulate their depth or not, this research will use McCrary's test.

Additionally, we can see there is a drop and jump in an area around 11-12 meters. However, those changes are the results of ports that has a depth of almost 12 meters manipulate its depth. The ports dredged seafloor to accommodate Panamax container ship that was standard in around 1972 to 1985.



Source: Author's data analysis, 2020.

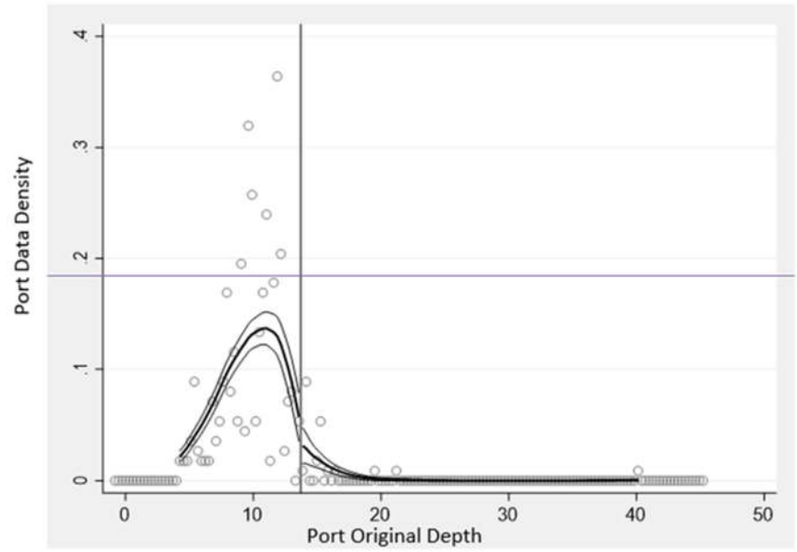
Figure 4. Ports' Original Depth Distribution

2. McCrary's Test

The further investigate a slight drop before the cut-off that we found in Figure 4, we do a test from McCrary (2008). With this test, we check if the port manipulates its depth by dredging the container terminal in 1972-1985 to accommodate Post Panamax Container Ship.

Figure 5 shows the result of McCrary's Test. The result of the estimated jump is -0.3794, and the Standard Error is 0.3526. T statistic value is -1.0760, which is not significant. This result shows no jump in the treatment because of manipulation in the running variable used, which also answers our earlier question regarding the slight drop in the histogram area around 11-12 meters. Due to this test, we can safely

claim that there is no manipulation if port purposefully wants to accommodate Post Panamax Container Ships from 1972 to 1985.



Source: Author's data analysis, 2020.

Figure 5. McCrary"s Test Result

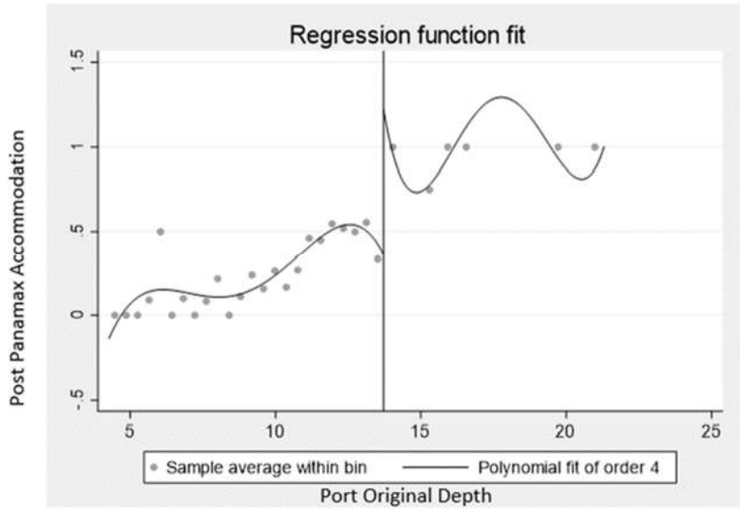
Main Result and Analysis

Table 2. Sharp RDD on Post Panamax Accommodate to Current Ports' Depth

Outcome Variables	Port Accommodated Post Panamax Container Ship
Treatment	Original Depth >= 13.716 meters
Treatment Eff. Est.	0.7756 ***
	(0.2362)
Running Variable	Original Depth
Cut-off	13.716 m
No. of obs	399

Note: Standard errors are in parentheses. Significance levels are using robust method where ∗ for p < 0.10, ∗∗ for p < 0.05, and ∗∗∗ for p < 0.01.

Table 1 shows that the sharp RDD calculation is using 399 ports shows the result is significant at 99 per cent using a robust method. The significant result shows that the ports with actual depth more than 13.716 meters, tend to accommodate the Post Panamax container ships. Consequently, the actual ports' seafloor depth affects significantly to ports decision to accommodate Post Panamax container ships.



Source: Author's data analysis, 2020.

Figure 6. Discontinue Around Cut-off

The graph in Figure 6 illustrates there is a jump of outcome in cut-off point. In the area around the cut-off is the bandwidth area where we count the Local Average Treatment Effect (LATE). The result can only prove the causality in the bandwidth area. The running variable's jump shows that a port with a depth of more than 13.716 meters will be inclined to accommodate a Post Panamax container ship. Ship sizes economies between Panamax container ship and Post Panamax container ship only change slightly (Veldman, 2011, p.31). The economies of ship size might be why many ports are reluctant to dredge their container terminal to accommodate Post Panamax container ships. Although the ship size economies have a minuscule difference, Veldman (2011) shows a high trade increase from 1990 to 2007, when the Post Panamax container ship is active. It shows that the Post Panamax container ship correlates with a high increase in trade. Consequently, port that accommodates Post Panamax container ship gained an increase in trade.

To quantify the trade increase resulting from the Post Panamax container ship, we need an exogenous variable. Brooks et al. (2018) use a port with a depth of 9.144 meters (30 feet) as an IV. However, depth cannot be used directly as an IV because it violates exclusion restriction. For Instance, a region with a deep-sea might be thriving from the fishery, and a region with a shallow sea might be impoverished. Thus, we cannot compare both regions because they are different. To counter that problem, we can use fuzzy RDD. Bilotkach et al. (2019) apply the cut-off of the maximum distance of common use low-cost carriers plane to quantify the airplane's effect on passengers' number. Similarly, we can quantify the effect of introducing a Post Panamax container ship using the cut-off of port's minimum depth to accommodate a Post Panamax container ship.

Robustness Check

Ensuring the result is dependable, we also have done several robustness checks. There are two tests that are commonly performed on RDD, which are higher

order polynomial test and placebo test. In this research, we did we placebo tests to make sure that the results were not a random phenomenon.

1. Higher Order Polynomial Test

The first robustness check is to test the result's sensitivity. By running it into a higher-order polynomial, we can check if the result is sensitive or not change in a higher polynomial.

To test the sensitivity of the result, we run the same model to a higher polynomial. After we run it at second-order local polynomial, the result is still significant at a 95 per cent level of confidence. It means that the result is not sensitive at second-order local polynomial.

Table 3. Sensitivity Test at Second Order Local Polynomial

Outcome Variables	Port Accommodated Post Panamax Container Ship
Treatment	Original Depth >= 13.716 meters
Treatment Eff. Est.	1.0393 ***
	(0.4493)
Running Variable	Original Depth
Cut-off	13.716 m
No. of obs	399

Note: Standard errors are in parentheses. Significance levels are using robust method where ∗ for p < 0.10, ∗∗ for p < 0.05, and ∗∗∗ for p < 0.01

2. Placebo Tests

After the first check shows that the result is not sensitive and still significant at the second-order local polynomial. We did the second robustness test to check discontinuity on artificial cut-offs. This test will prove that at arbitrary cut-offs or meaningless cut-offs, the result will become insignificant. Table 3 shows that using cut-offs of 13 meters and 15 meters. Because there is no notable ship draft at that point, the result is not significant.

Table 4. Checking Discontinuity on Artificial Cut-offs

Outcome Variables	Port Accommodated Post Panamax Container Ship	Port Accommodated Post Panamax Container Ship
Treatment	Original depth >= 13 meters	Original depth >= 15 meters
Treatment Eff. Est.	-0.0063 (0.1504)	-0.22689 (0.2186)
Running Variable	Original Depth	Original Depth
Cut-off	13 m	15 m
No. of obs	399	399

Note: Standard errors are in parentheses. Significance levels are using robust method where ∗ for p < 0.10, ∗∗ for p < 0.05, and ∗∗∗ for p < 0.01.

We are not just stopping investigating at the placebo cut-off. To further prove the result's robustness, we also change the outcome value for placebo cut-offs of 13 meters and 15 meters to current port depth more or equal to 13 meters and more or

equal to 15 meters, respectively. This change is needed to show that the original cut-offs and outcome at 13.716 is not just because of some random accident.

We also check discontinuity on artificial cut-off and outcome. This robustness check has a slight difference with previous robustness. In this robustness check, we set the outcome to be at the same depth of the current depth and the cut-off. The result in Table 4 is statistically not significant, meaning that even if we pick a random outcome and cut-off without any justification, there will be no discontinuity around the cut-off.

Table 5. Checking Discontinuity on Artificial Cut-offs and Outcome

Outcome Variables	Port Current Depth >= 13	Port Current Depth >= 15
Treatment	Original depth >= 13 meters	Original depth >= 15 meters
Treatment Eff. Est.	0.1895	3.9447
	(0.1153)	(0.9982)
Running Variable	Original Depth	Original Depth
Cut-off	13 m	15 m
No. of obs	399	399

Note: Standard errors are in parentheses. Significance levels are using robust method where $*$ for $p < 0.10$, $**$ for $p < 0.05$, and $***$ for $p < 0.01$.

These tests show that the result both for placebo cut-offs and also outcomes are not significant. Furthermore, the result from manipulation and McCrary's test shows that the data is not sensitive, and the jump is not just some random phenomenon. Therefore, the jump in the running variable only explanation is because of Post Panamax Container ship draft.

CONCLUSION

The rapid development of Container Ship benefits the ports with actual depth more than 13.716 meters; hence, the ports can quickly adapt to Post Panamax container ship standard. Besides, newer container ship generation has considerably higher TEU capacity, mean that the ports that accommodate newer container ship will also get higher container trade. Unfortunately, this research is limited to find those port level trade data.

The high adaptation rate to accommodate Post Panamax II container ships is a further evidence that the trickle-down-effect of mega ships exists. The container ships dimension is built to be more efficient than the Panamax container ship and more versatile to sails in many trade routes including the one that get through the new Panama Canal lock that still cannot be crossed by mega ships. Consequently, by accommodating Post Panamax II container ships will bring more commodities to the ports efficiently. To catch the opportunity, Ports must provide the infrastructures needed and dredge their sea floors in accordance to draft of Post Panamax II container ships (13.716 meters).

Another benefit of this research is the potential use of the cut-off (Post Panamax depth) and the running variable (actual ports' depth). The cut-off and the running variable are an exogenous variation that is significant and robust in bandwidth area.

In the future, researchers can quantify the causality of trade at port utilize the cut-off and running variable of this research.

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