GIBRAT'S LAW AND PORT GROWTH

by

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The purpose of this paper is to examine ports growth, specifically whether or not port growth is independent of port size. It uses total exports as a measure of size and use the average as estimate of growth rate and specifically analyzes the growth rates of United States Custom's Ports. Through using various tests, the findings conclude that larger ports in the beginning of the period have higher growth rates than parts with lower total exports at the beginning of the period. The conclusion of this finding is that physical limitations inhibit a port's ability to grow, and thus larger ports have a higher growth rate than smaller ports.

Acknowledgements

I would like to thank Professor Wilson, Professor McGough, and Professor Sandler for helping me to fully examine the specific topic and consider the various perspectives and contexts related to this subject matter.

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Introduction

Ports have always held an important role in international trade by acting as the gateway for people and goods. In the last twenty years, ports have expanded and grown as the international market and globalization of the world has pushed ports to meet the increasing demand for centers to facilitate entry and exit of goods. Ships and liners are also the most economic mode of transportation and are the safest and most economical mode of transportation for large quantities. The United States depends heavily on ports and inland trade to facilitate its economic growth. U.S. seaports alone are responsible for moving nearly all of our international trade and accounted for more than 32% of U.S. GDP in 2012[1]. Ports play a vital role in facilitating trade and when port facilitation is disrupted by congestion issues or problems, the impact is felt throughout the country.

U.S. ports serve as the connection between small businesses in the U.S. and the international market but it also serves to connect businesses abroad to consumers here. Besides accounting for nearly a third of GDP, a ports efficiency and functionality also heavily influences the international trade market because it is the sole means of facilitating 99.4% of international trade. According to Admiral John C. Harvey Jr., Commander of the U.S. Fleet Forces Command, "… we live in a global economy where 90% of all commerce is transported by ship…" (U.S. Army Corps of Engineers, 2012). A port's ability to transport trade across oceans and land has helped the U.S. grow. But, as demands grow, ports must also grow to accommodate those changes.

The ability of U.S. ports to compete internationally is declining. In 1935, New York City had the world's busiest port, but during the last 50 years, the concentration of

[1] (U.S. Army Corps of Engineers, 2012)

port activity has shifted to Asian countries such as Hong Kong, China, Japan, and Taiwan as these nations have become the international centers of trade and commerce[2]. Since these nations also built their port infrastructure later, the ports were able to implement new technology and dredge channels to accommodate the larger ships that have become so used today. Many ports within the U.S. are currently spending billions of dollars to renovate and expand their channels.

If the goal is to expand ports in the hopes of improving trade overall in the U.S., an important part of making this decision is knowing which ports to expand. Should only large ports be expanded or would it be more economical to expand small ports? Thus, understanding the role of initial size and state of the port is necessary for making this decision.

This paper first examines the importance of ports and their role in international trade and their importance for growth in the economy. It attempts to test if a ports ability to grow and accommodate the growing demand for ports and the growing size of ships is dependent on its initial size. The paper uses a basic comparison for growth rates to show that small ports have higher growth rate than large ports in the short run. Using two data sets, Portualia and WPI, total trade and total TEU's are used as the measure for size and their rate of change as the average growth rate. Two datasets are used in order to test if Gibrat's Law will still hold under certain conditions. The estimated linear model initial size has a negative relationship with the growth rate, thus breaking Gibrat's Law. The paper then postulates that previous theories of growth drawn from studies on Gibrat's Law are also applicable to ports.

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[2] (Alderton, 2005)

The findings of this study is that ports do not obey Gibrat's Law and have similar behavior to firms. Small ports have higher variability in growth rates than large ports, but when looking beyond a ten year interval, both large and small ports converge to the same growth rate. Thus, in the short run, initial size has a negative relationship with growth rate, which is not sustained in the long run.

The next section provides a background on Gibrat's Law and the current state of U.S. ports comprehensive literature review of port economics and theory on firm growth. The following section outlines the methods of testing Gibrat's Law for ports and a description of the data. The last section after displays the results along with an analysis of future steps.

Background

Each coastal state in the U.S. has at least 15 seaports handling international commerce and trade. These ports not only handle trade, but also have jurisdiction over airports, bridges, tunnels, railroads, barges, and industrial parks[3]. Ports play a major role in the regional economic development and in industrial plant location and continue to be the main source of transportation of goods in international trade because of their low cost per ton compared to other modes of transportation. A report released by the Army Corps of Engineer in June 2012 titled *Port and Inland Waterways: Preparing for Post Panamax Vessels* found that ports on the East and Gulf Coasts have sufficient used and unused physical capacity in the near term. Since the more cargo a ship can carry means more goods to handle, ships continue growing in size and ports must match this growth in order to continue to stay competitive with other ports. Since ports are such an integral aspect of U.S. trade, it is pertinent that U.S. customs ports can match this growth and accommodate large ships.

Currently, ships are growing to match increasing demands for trade. Panamax and New Panamax are the terms for size limits for ships going through the Panama Canal. Panamax ships could fit in the Panama Canal before the renovation, and New Panamax ships are currently too large but will fit after the expansion. With the expansion of the Panama Canal so that it can facilitate larger containerized ships, ports in the U.S. must account for this increase in demand for service from larger ships, especially New Panamax ships. Ports on the west coast are operating near full capacity but are able to handle the New Panamax ships, while few ports on the east coast can

[3] (U.S. Army Corps of Engineers, 2012)

service the larger ships (U.S. Army Corps of Engineers, 2012). The task of renovating and expanding ports has high financial and environmental costs, but are necessary for these ports to remain as competitive. New Jersey and New York have committed $4 billion dollars in expanding the port to prepare for the effects of the renovated Panama Canal (U.S. Army Corps of Engineers, 2012). With the growing demand and constant technological changes, ports are hard pressed to match these changes, quickly, and cost efficiently.

This paper measures the relationship between port size and port growth, specifically testing Gibrat's Law. Gibrat's Law was created by Robert Gibrat in 1931 and is "one of the most important strands in the literature on market structure… and is the first formal model of the dynamics of firm size and industry structure" and is also known as the Law of Proportional Effect (Sutton 1997). Gibrat first used this law to model income distributions and plant sizes in manufacturing and noticed a striking parallel quality in the growth rates of small plants and large plants. Gibrat formally published his findings in *Les Inégalités économiques* and his formal law is that a firm's growth is independent of firm size.

Gibrat's Law was studied extensively in the 50's and 60's without the same success in results as Gibrat's first study with the manufacturing plants. In fact, most studies "cast doubt on the idea that proportional growth rates were independent of firm size" (Sutton 1997). But in 1962, Edwin Mansfield, whose test is used in this study, pioneered a simple, new test. Gibrat was restricted by time and computational power in modeling his data, but Mansfield's test looked at the ratio between final size and initial size compared to groups of varying sizes. Mansfield also reached the important conclusion that Gibrat's Law, although not binding, may hold if the industry had no exit or entry.

In 1984, David Evans used the result of Mansfield's study and research to produce his own theoretical, linear model for testing Gibrat's Law. This tests uses the average growth rate of a firm, *Avg*, and sees if initial size is a factor. Evans tested the study on 100 manufacturing plants in England and found that Gibrat's Law held in the long run for large firms. He attributed the difference to the variance in exit and entry rates between large firms and small firms. Large firms had a significantly lower exit and entry rate than smaller ports, which seemed to agree with Mansfield's conclusion that Gibrat's Law can hold when controlling for exit and entry of firms.

The models and theory of Mansfield and Evans are included in the section titled, "Conceptual Model." Given this extensive research, the hypothesis of this study is that ports do not obey Gibrat's Law, and in fact, smaller ports will have a higher growth rate than large ports.

Literature Review

Port economics is a vast field that has been researched and studied in the past century. The purpose of this paper is to find which factors affect port growth and analyze previous studies on Gibrat's Law. Thus the following literature review examines the methods and practices of the world's leading ports along with theory on firm growth. The order of articles chosen for review start with port economics, to firm theory, and end with Gibrat's Law. In this section, a broad overview of the current state and issues of port affairs covered along with theories on Gibrat's Law that is pertinent to this paper.

One importance facet of port economics is management and efficiency of ports. An area of debate is the matter of whether a port is managed most efficiently when privately or publicly owned. In Alfred Baird's study in 1999 finds that the world's seven largest ports are privately managed and publicly owned. Within port management, there are three parts that can be privatized: the role of port regulator, port landowner, or port operator. The paper outlines the responsibilities of these three roles along with the definition of 'public' and 'private.' Baird also covers the different levels of being privately owned which is included in the table on the following page.

Port Models	Port Regulator	Port Landowner	Operator
Public	Public	Public	Public
Private/I	Public	Public	Private
Private/II	Public	Private	Private
Private/III	Private	Private	Private

Table 1

Out of the world's 100 biggest ports, eighty-eight are Level I private, only seven are completely public, two are Level II private, and three are Level III private (Baird, 1999). Baird concludes that private management is more efficient, but if privatization is at the third level, ports have no incentive to expand due to the high cost of capital. Level I has the most benefits because cranes and terminals are privately managed but the responsibility of expanding the port is the government's responsibility.

Currently, the world's largest ports are in Asia and thus their management structure and methodology should be studied. In Kevin Cullicane and Dong-Wook Song's examined the management and regulatory practices of ports in Taiwan, Hong Kong, China. The goal of the paper was to "review the administrative and ownership structures of major container ports in Asia" (Cullicane & Song, 2001). The paper examined in depth the management and operational structure of ports in Taiwan, Hong Kong, and China, along with the different regulatory practices within each country.

The authors found that in the past decade, container ports and terminals of Asia and utilize a hybridization of public and private involvement. "Securing efficiency gains in the port sector is perceived as critically important for maintaining and enhancing the competitiveness… and that the competitiveness of a nation's port… is directly linked to a nation's prosperity (Cullicane & Song, 2001)." This motivates the government to continue opening terminals for private investment and relaxing regulations, which increases efficiency along with the competitiveness of the port. The authors also mention that the notion of public ownership is associated with reduced inefficiency, further justifying the claim that private management is better.

Another important observation of Cullicane and Song is the role of competition between ports in improving port management and efficiency. The overlapping and expansion of port hinterlands have caused a general improvement in fort transportation and efficiency (Cullicane & Song, 2001). Ports that face more competition are more efficient regardless of public or private ownership.

An added facet to port competition besides competition between ports, is competition within a port, or intraport competition. Langen and Pallis provide an in depth analysis of intra port competition that extends beyond the consumer perspective. Intra port competition is when different terminals within the same port are competing for the same share of market. Port competition increases efficiency because it reduces ports incentives to charge tariffs and reduces monopoly, overall benefitting consumers (Langen & Pallios). Another argument favoring intraport competition is the specialization and regionalization port terminals.

A method of creating intraport competition is to open up investment of terminals to private firms who can claim ownership and management of terminals. "A port with different port service providers, with different production models is superior to a port with one service provider," which also promotes the idea of regionalization and specialization between terminals (Langen & Pallios). Intraport competition forces port operators to fight for their share of the market through diversifying services and products, which overall helps the port.

Given the cursory background of port economics, this study treats ports as firms. Firm is defined as a business or organization involved in the transaction of goods and services. The following are characteristics that ports have that similar to firms. One, ports face competition and in fact perform more efficiently with the presence of interport and intraport competition, similarly to firms. Two, privatization within ports is becoming increasingly more common thus are beginning to be operated and managed as firms, and, third, ports provide services to ships and liners for a monetary fee. One notable difference between firms and ports is the ability to exit and enter the port industry. Due to high costs in capital, the exit and entry rate of individual ports is nonexistent.

Gibrat's Law is a simple law that is complicated by firm and industry attributes and other characteristics that affect the verity of the law. Audretsch also varies the time periods of firms, which is relevant to the effects of Gibrat's Law on ports. "… the influence of the technological regime and market structure on firm survival apparently varies considerably with the time interval considered," with innovation having a positive influence for small firms in the four-year period, but not in the ten-year period (Audretsch, 1991). Audretsch's paper suggest that although small firms grow faster in the short run when given new technology, in the long run, this effect disappears and cannot sustain this higher growth rate for small firms. Despite exit and enty within ports is nearly nonexistent, the observation of distinction between short run and long run effects is relevant.

David Evans research provides the basis for how Gibrat's Law is tested in this paper. Much of his methodology and conclusions is discussed in the introduction and the following section. Evans ultimately concludes that smaller firms have higher variability and larger growth rates, which decreases as the firm (if it survives) grows and ages. Thus, a negative relationship exists between growth and size. But, "the departures from Gibrat's Law decrease as firm size increase," implying that large firms do obey Gibrat's Law. The methodology and conceptual model of Evan's paper is covered in the following section.

Methodology

The most basic model of Gibrat's Law is used by Edwin Mansfield in 1962 which simply compares the growth rates of small firms over a period time, *T*, to larger firms over the same period of time. For the purpose of this paper, port size is defined as the total twenty foot ton equivalents (TEU's) handled by a port in year, t. Although total exports, measured in U.S. dollars, is another common measurement for port size, ports differ in their measurement of the worth of cargo due to varying circumstances, such as tariffs and taxes that affect the accuracy of that data. TEU's, although not exact, is a measurement used globally by ports to measure shipment size and is not affected by the valuation of goods. Since a port's purpose is to serve as a point of entry for goods and services, it is appropriate to then measure a port's growth and size by the level of total TEU's it handles each year.

These ports are then separated into two even groups so that the growth rates between each size group can be compared. The method of grouping of port sizes is arbitrary, but it helps to compare the growth rates of smaller and large sized ports. For this test, the ports are simply divided in two even groups of thirty-three each. Using Mansfield's test for Gibrat's Law, I test the size distribution of:

$$Mansfield = \frac{S_t}{S_{t'}}$$

S_t = Total TEU's in time t

S_t =Total TEU's in time t'

t' = Final year

t = Initial year

The results of Mansfield test show that the small ports have a higher growth rate than the larger ports. The histogram of size ratios for the smaller ports shows none of the growth rates are zero and is actually skewed to the right. For large ports, none are centered on zero, but the data is more centered on one. This extremely basic test already indicates that ports do not obey Gibrat's Law.

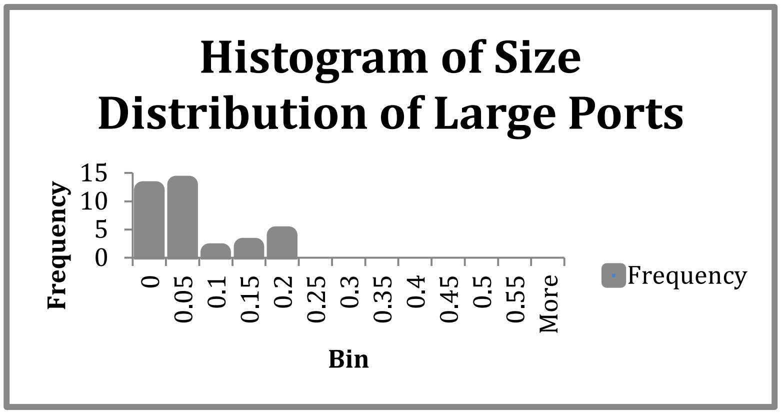

Figure 1

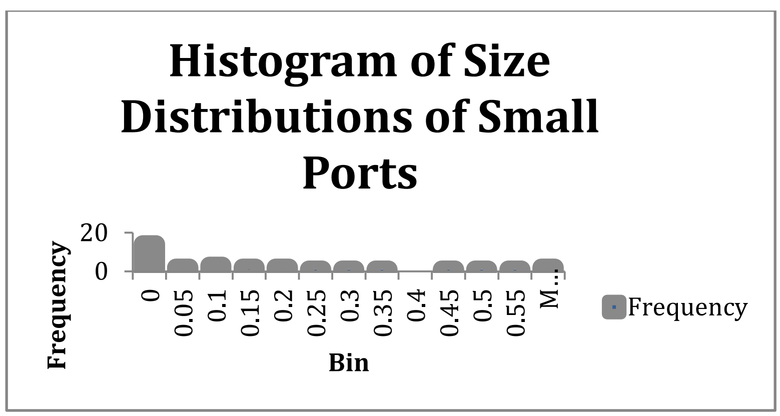

Figure 2

From Figure 1, larger ports have a growth rate centered on 1 while smaller ports have growth rates ranging from 1 to 10 or more and are not as centered as large ports. Larger sized group has less variability than the smaller ports, which follows the conclusions of Evan's tests. The smaller ports graph has a longer tail towards the higher growth rate, indicating that a sizable portion of small ports have a growth rate higher than 1%. Although the table shows that smaller ports have a higher growth rate than larger ports, the Mansfield's test is unable to provide any explanation for the differences. David Evans in his study on firms however, can provide an equation that gives insight on Gibrat's Law and factors of growth.

The method of testing Gibrat's Law follows Evans (1987) with modifications to the measurements of capital and size. The model is estimated by equation (1) and is based off of Evans' model:

$$Avg = \alpha + \beta_1 Size_t + \beta_2 PC + \varepsilon_i \qquad (1)$$

Avg represents average growth rate $= \frac{\ln Size_{t'} - \ln Size_t}{t' - t}$ and is the dependent variable.

Size is an independent variable and is measured by total twenty-foot equivalent units (TEU) handled by the port in one year, t. With Mansfield's model showing that smaller ports have a higher growth rate, β_1 should have a negative coefficient. PC_i represents other physical characteristics of the port that could affect the growth rate. Ports have many physical characteristics such as tide, channel depth, and number of piers that can affect the sign of β_2. These variables are harder to measure due the changes in tide and temperature that can affect the accuracy of this measurement. Physical characteristics that inhibited ship passage or limited port capacity, such as channel depth or terminal space, were included in the model. Since each physical characteristic has a different effect on growth rate, I expect both positive and negative coefficients. The results are shown in the following section.

The model is run on two separate measures of size, one with TEU's, and the other with total trade. TEU is first tested, and the total trade.

Data

The data used to measure size and the average growth rate came from two different sources, Portualia and the Army Corps of Engineers.

The dataset with the data on size in terms of TEU's came from the Army Corps Engineers dataset, "Containerization by U.S. Ports," which is accessible on their website.[4] The Army Corps of Engineers has data on total TEU's handled by a port per year starting from 2007 and ending in 2012. TEU is the measurement for Size in the model. The data was collected by the Port Import Export Reporting Service (PIERS) using Vessel Manifests and Bills of Lading. According to the notes the statistics include all shipments in out of U.S. but exclude shipments between the 50 states and U.S. territories, i.e. Guam and Puerto Rico. Using Portualia, the two datasets were merged by US Port Code and Port Index Number in order to create one complete dataset with around 80 data entries where the units of observation is US Port Code, year, the natural log of TEU's in the same year, and some physical characteristic. The natural logarithmic form of the data was used in order to represent the percent effect the starting year's size had on the average growth rate, which is also measured through natural logs. The reliability of this data is strong since PIERS is a reliable and reputable data collecting agency that is often used for studies on ports.

Many ports in the U.S. do not handle TEU's so those ports were dropped in order to not skew the data. Since these ports have no growth, the inclusion of these data points would skew the results downward. The final data size was sixty seven. This same

[4] http://www.navigationdatacenter.us/data/data1.htm.

dataset was used to test Mansfield in order to maintain consistency. This dataset also only had the measurements for the years from 2007 to 2012.

An issue with this dataset was that many ports had zero or one total TEU's in a year, which would cause the average growth rate to equal zero. Part of this is since TEU's is such a large unit and requires certain port facilities and services. Thus ports that do handle TEU's would be omitted from the study. Due to the shortcomings of the Army Corps data set, Portualia, is also tested. Not only does it use another method of measuring size, total trade, but Portualia has a longer time interval, which could change the results of the linear estimation. Another benefit is that overall, Portualia has more data points.

Portualia includes yearly data on imports and exports for each U.S. customs port from 1991 to 2009, and the World Port Index supplemented the port data with data on the physical attributes of each port. Any of the data sets missing import or export data was deleted. The final dataset was one hundred and one. This dataset ranged from the years 1991 to 2009, but only the data from 2000-2009 was used in order to best compare with the Army Corps dataset. I chose to compare with two datasets to also test if valuation of size would change the results and also to be able to include the ports excluded in the first dataset. Another benefit of Portualia is that the dataset spans eighteen years, which is useful in testing the effect of time interval on the results. Since imports and exports are measured in U.S. dollars without adjusting for inflation, this was corrected for by chaining the data to 2000.

Portualia had many missing data points in imports and exports and I had no way of looking for an updated dataset since Portualia no longer exists. This dataset did exist on Portualia.com and is cited as the source of data for many prominent transportation journals. But, since the source doesn't exist, there is no way knowing how the data is measured or any way of updating the data.

The World Port Index (WPI) provided the data for physical characteristics of the ports. The WPI is under the Maritime and Safety Information which annually publishes Publication 150, or PUB150, with updated statistics on physical characteristics of ports.[5] WPI is a government funded agency and collects its data using information given by ports. This data was used to construct the PC variable. The data on physical characteristics were categorical and dummy variables that were converted to natural logarithms in order to measure percent effect. Discrete categorization is used for measurements such as channel depth due to the variability of the measurement caused by the environment. For example, with tide, channel depth can vary depending on when it is measured. Thus, channel depth is measured by the maximum ship size that can pass through the port channel. In the WPI dataset, the discrete measurement was categorized by letters rather than numbers, which I transformed into numbers in order to run OLS in Stata. There is always a zero in each category in order to avoid the dummy variable trap.

[5] http://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0015.

Channel Depth				Harbor Size			Cargo Pier Depth			
Depth Code	Feet	Meters	OLS code	Harbor Size Code	Harbor Size	OLS Code	Depth Code	Feet	Meters	OLS Code
A	76ft - OVER	23.2m - OVER	0	L	Large	1	A	76ft - OVER	23.2m - OVER	0
B	71ft - 75ft	21.6m - 22.9m	1	M	Medium	2	B	71ft - 75ft	21.6m - 22.9m	1
C	66ft - 75ft	20.1m - 21.3m	2	S	Small	3	C	66ft - 75ft	20.1m - 21.3m	2
D	61ft - 65ft	18.6m - 19.8m	3	V	Very Small	0	D	61ft - 65ft	18.6m - 19.8m	3
E	56ft - 60ft	17.1m - 18.2m	4				E	56ft - 60ft	17.1m - 18.2m	4
F	51ft - 55ft	15.5m - 16m	5				F	51ft - 55ft	15.5m - 16m	5
G	46ft - 50ft	14m - 15.2m	6				G	46ft - 50ft	14m - 15.2m	6
H	41ft - 45ft	12.5m - 13.7m	7				H	41ft - 45ft	12.5m - 13.7m	7
J	36ft - 40ft	11m - 12.2m	8				J	36ft - 40ft	11m - 12.2m	8
K	31ft - 35ft	9.4m - 10m	9				K	31ft - 35ft	9.4m - 10m	9
L	26ft - 30ft	7.1m - 9.1m	10				L	26ft - 30ft	7.1m - 9.1m	10
M	21ft - 25ft	6.4m - 7.6m	11				M	21ft - 25ft	6.4m - 7.6m	11
N	16ft - 20ft	4.9m - 6.1m	12				N	16ft - 20ft	4.9m - 6.1m	12
O	11ft - 15ft	3.4m - 4.6m	13				O	11ft - 15ft	3.4m - 4.6m	13
P	6ft - 10ft	1.8m - 3m	14				P	6ft - 10ft	1.8m - 3m	14
Q	0ft - 5ft	0m - 1.5m	15				Q	0ft - 5ft	0m - 1.5m	15

Table 2

Empirical Results

OLS is applied to equation one for each year starting in 2007 and with 2012 as the final year with estimates given in Table 1. Before discussing the results, I first describe the the general fit and efficiency of the model. This gives estimates on size that vary over time. In addition, growth rates are measured differently depending on the dataset. The below results and conclusions use TEU as the measure size and average growth rate.The fit of the model has R^2 values ranging from .03 to .15, indicating that our independent variable can only explain up to 15% of the average growth rate depending on the year. Despite this, nearly all the years, except for 2010 and 2011 are significant, which is confirmed by the T-statistic associated with the variable for starting size. Even after correcting for heteroskedasticity, the coefficients are not significant.

In general, the results follow the predictions given by Mansfield's table. Since the independent variables are in logarithmic form, the coefficients are also indicators for elasticities. The coefficients range from -.003 to .4 during 2007-2011, implying that a 10% increase in initial size decreases the average growth rate by .03% to 43%.

Year	**Untreated coefficient for Size$_t$**	**Standard Deviation**	**t**	**Coefficient for Size$_t$**	**Robust St. Dev.**	**t**
2007	-0.0156522	0.0096073	-1.63*	-0.01133	0.007822	-1.45*
2008	-0.0309398	0.0117738	-2.63*	-0.03094	0.012749	-2.432*
2009	-0.431666	0.012878	-3.35**	-0.04317	0.012352	-3.49**
2010	-0.0266265	0.0204844	-1.3	-0.02663	0.022822	-1.17
2011	-0.0035821	0.0288524	-0.012	-0.00358	0.025077	-0.14

Table 3

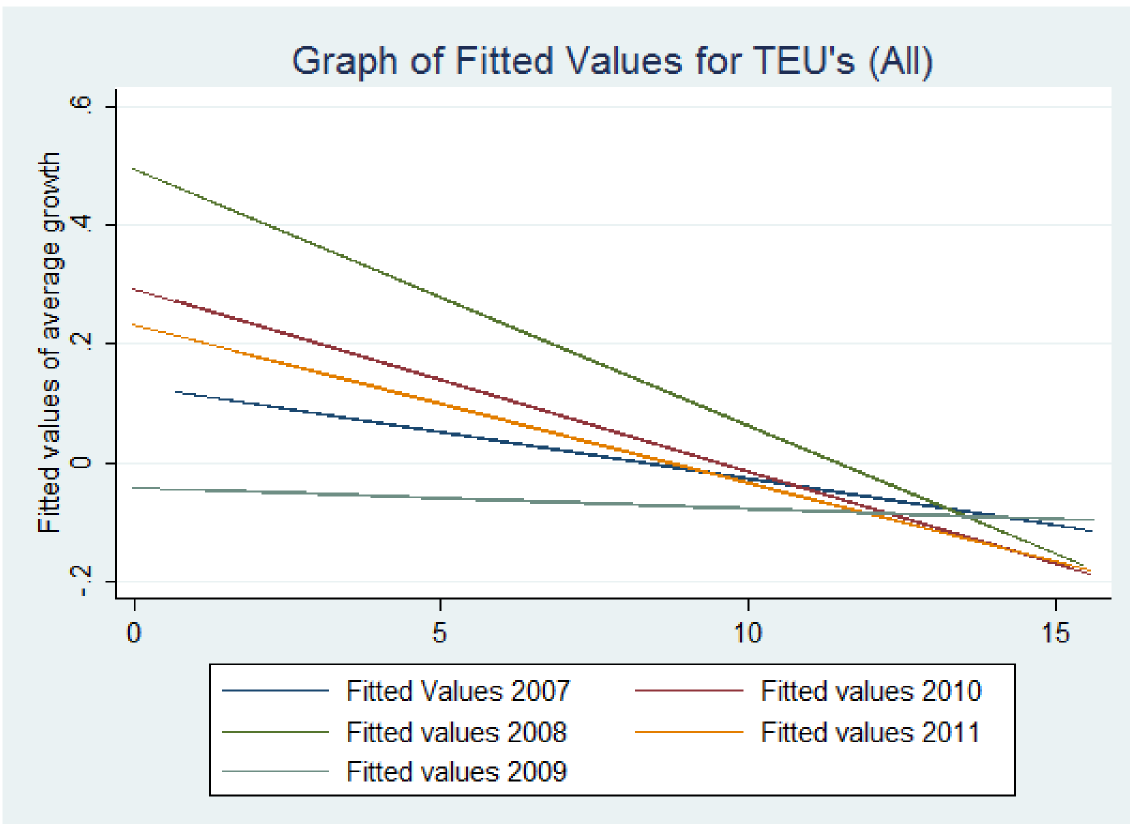

Figure 3

All the results show a negative relationship between the dependent variable, Avg, and the independent variable, starting size. This result is consistent with the conclusion of Mansfield’s results. The negative relationship can be explained by the ability for ports to adapt to technological or management changes. Due to scale, smaller ports are able to increase their size faster than larger ports (Evans, 1987). For example, if a small port of only seven TEU's a year were to add one crane, the port could handle more goods and increase size with a larger average growth rate than a port that handled thousands of TEU's from the increase of one crane (Alderton, 2005). Part of this is scale since larger ports have to dedicate more time and resources to successfully implement new technology or new methods whereas smaller ports have less area and region to occur. Another reason is that smaller ports do not have to spend as much money in improving changes as larger ports.

In the models testing physical characteristics, the coefficients were never significant for any of the years and would also make the coefficient for size insignificant also. Even after correcting for heteroskedasticity, the coefficients were not significant. Part of this is because initial size is already affected by physical characteristics. For example, smaller ports tend to have less channel depth than larger ports and so are already disadvantaged in terms of a port's ability to grow. The initial size variable already captures the effect of the physical characteristics and so were excluded from the final model.[6]

Since both Evans and Audretsch's studies conclude that larger firms have a lower growth rate and less variability, the same model can be run separately on the large ports versus the small ports. The data was divided evenly in half and the same linear regression was run on both models with varying results.

[6] If interested in seeing the model with physical characteristics, please look in the appendix.

Year	Untreated coefficient for $Size_t$	Standard Deviation	t	Coefficient for $Size_t$	Robust St. Dev.	t
2007	-0.0269	.0082115	-3.28	-0.0269	0.013341	-2.02
2008	-0.0528	0.0135226	-3.90	-0.05280	0.03652	-1.45
2009	-0.0566	0.01621	-3.49	-0.05662	0.37048	-1.53
2010	-0.00715	0.01599	-0.45	-.007148	0.02620	-0.27
2011	-0.04804	0.02705	-1.78	-0.048043	0.04823	-1.00

Table 4 – Large Ports

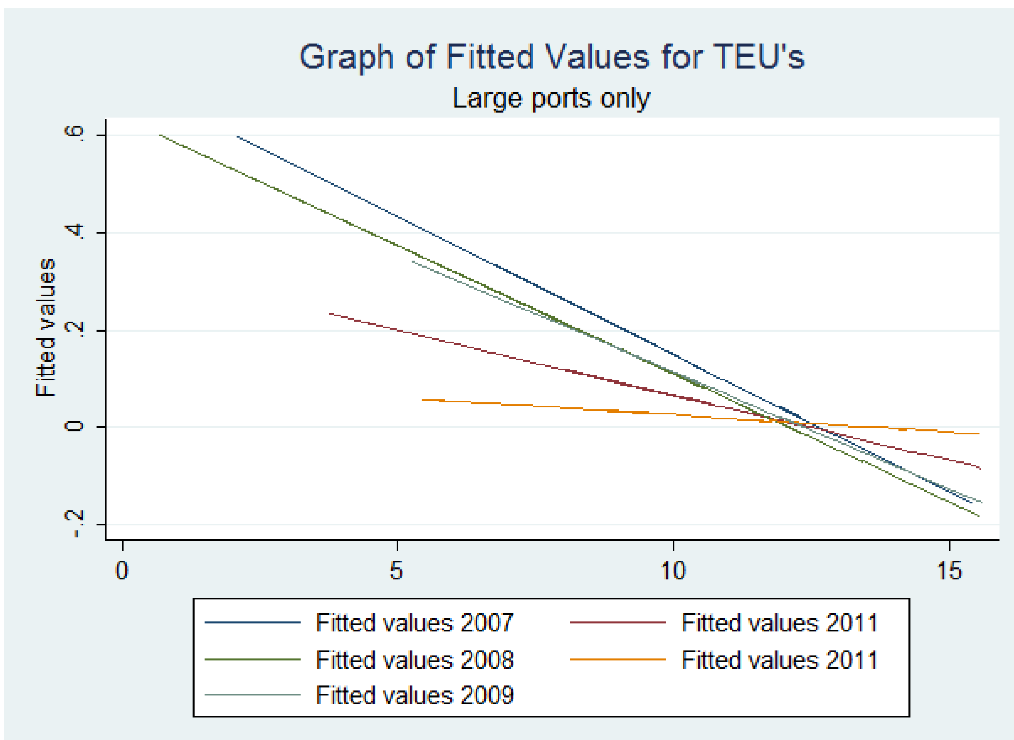

Figure 1

Year	Untreated coefficient for $Size_t$	Standard Deviation	t	Coefficient for $Size_t$	Robust St. Dev.	t
2007	-0.02465	0.01713	-1.44	-0.02465	0.01334	-1.85
2008	-0.04110	0.02253	-1.82	-0.04110	0.02453	-1.68
2009	-0.03860	0.02276	-1.70	-0.03860	0.01983	-1.95
2010	-0.02624	0.03691	-0.71	-0.02624	0.04143	-0.63
2011	-0.01572	0.04880	-0.32	-0.01572	0.03863	-0.41

Table 5 – Small Ports

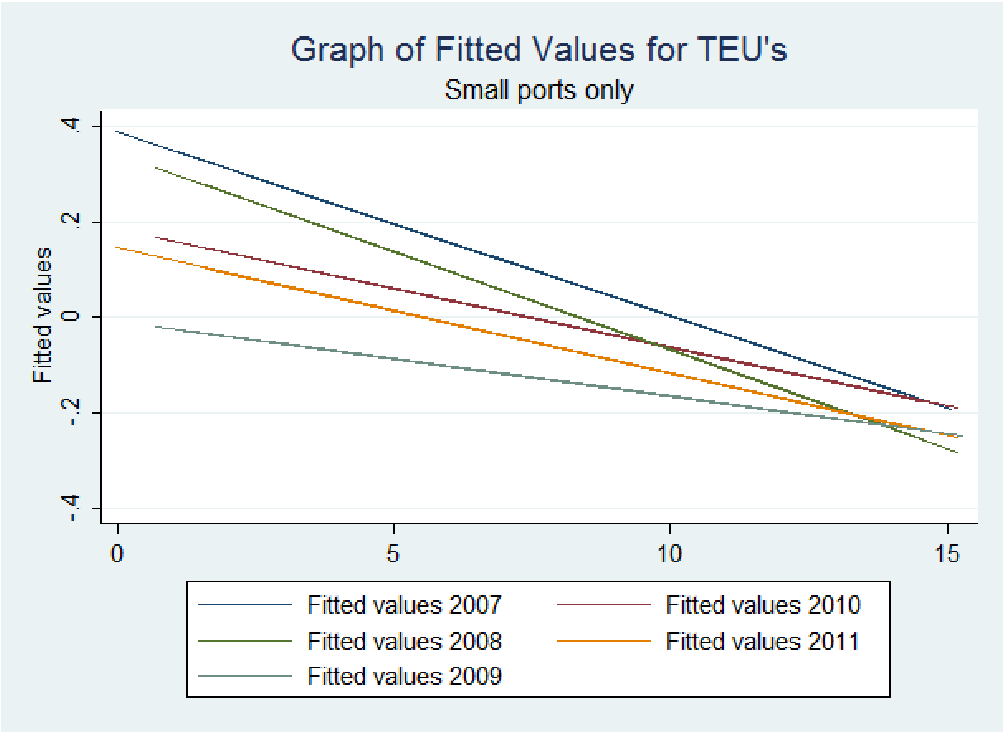

Figure 5

The R^2 value for the model on large ports ranged from .05 to .27, implying the model explained 5% to 27% of the data. For small ports, the R^2 ranged from .003 to .04, which is much lower than the R^2 value for large ports. Part of this is that smaller ports have higher variability, which means that the best fitting line using least squares estimator is much harder to fit than for larger ports. From Figures 4 and 5, the slopes for small ports are more negative than the slopes for large ports. Also, the curve for small ports have a longer length, but this decreases for the length of the curves in large ports.

Overall, the two tables do have a distinct difference between the growth rates of each year. From Table 4, the coefficient for initial size increases as the time period between initial and final decreases. This agrees with Evan's conclusions that large firms have greater growth rates in the long run as the coefficient in 2007 (-0.0269 > -0.04804) (Evans, 1987). This trend is also shown in Table 5. Small ports also has less negative coefficients, which also agrees with Evan's argument. Although larger ports have location advantage, these ports also must deal with congestion as ships grow larger and the number of ports able to service such ships becomes more limited. A high level of capital must be invested to either increase the capacity of these existing ports, or to increase the physical size and depth of other ports. In order to increase funding for ports and promote a more efficient management system, more ports should be privately managed (Baird, 1999)

Empirical Results – Portualia

A second method of measurement is used to see if this holds when size is measured in dollars. Using total trade as a measure of size, the results of this study were similar to the results obtained from using total TEU's as a measure of size. I run the same tests and models with the Portualia dataset merged with the WPI dataset. In this section, $Size_t = Imports_t + Exports_t$.

The new dataset was also split in two groups, one with the smaller ports, and another with the large and a histogram of size distributions was created. The TEU's in 2012 were ordered from smallest to largest and divided in half, with the thirty three small ports and thirty four large ports. Then, using the average growth rate in 2007, a histogram examining the frequencies of each growth rate was examined.

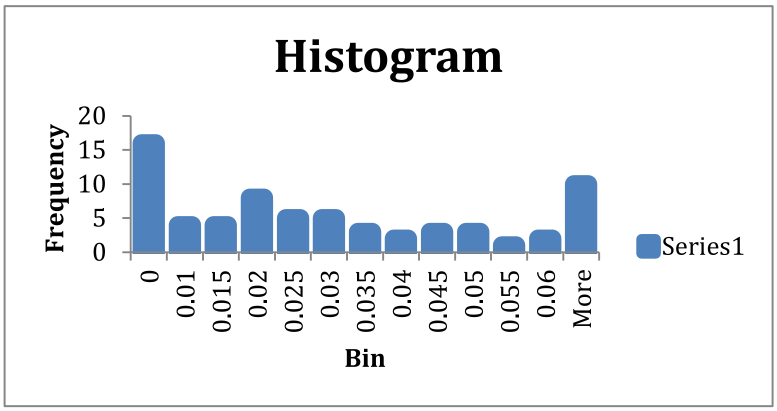

Figure 2 – Small Ports

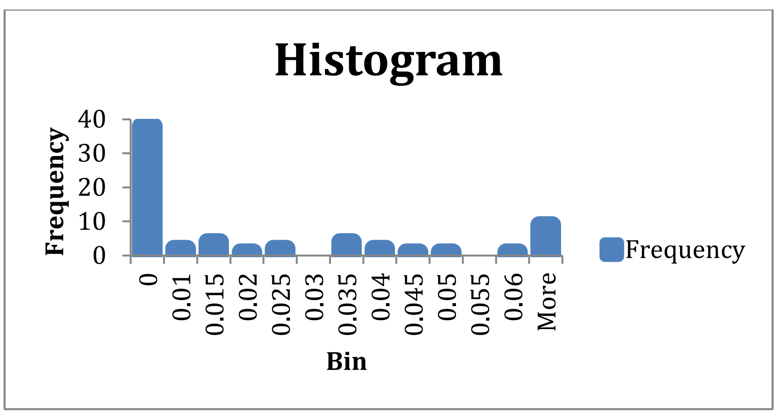

Figure 3 – Large Ports

Smaller ports have more variability and is skewed towards the right, while larger ports have a frequency of 40 that is centered on 0. It appears that even when valued by dollars, ports do not obey Gibrat's Law. If ports did obey Gibrat's Law, both graphs would have the same distribution. This distribution is similar to the Mansfield distribution given using TEU's as the measure of size.

OLS is applied to the same model but with the Portualia dataset with similar results.

Year	**Untreated coefficient for Size$_t$**	**Standard Deviation**	**t**	**Coefficient for Size$_t$**	**Robust St. Dev.**	**t**	**Year**	**Untreated coefficient for Size$_t$**	**Standard Deviation**
	Coefficient	Std. error	t	Coefficient	SD	t	Coefficient	SD	t
1999	-0.00528	0.01237	-0.04	-0.01635	0.004058	-4.03***	-0.00528	0.017457	-0.03
2000	-0.00732	0.00689	-1.06	-0.000241	0.003168	0.08	-0.00732	0.010679	-0.69
2001	-0.006	0.107139	0.56	-0.00241	0.004684	-0.51	-0.006	0.012373	0.48
2002	-0.00798	0.013643	0.58	-0.004448	0.004306	1.03	0.00798	0.014252	0.56
2003	-0.00307	0.011417	0.27	-0.01572	0.004343	3.62**	-0.003066	0.012461	0.25
2004	-0.07494	0.021752	-3.45**	0.001482	0.012163	0.12	-0.07494	0.037202	-2.01*
2005	-0.00421	0.029695	-0.14	-0.02533	0.010338	-2.54*	-0.00421	0.047017	-0.09
2006	-0.195624	0.028319	6.91***	-0.00584	0.007568	-0.77	0.195624	0.046501	4.21**
2007	-0.121334	0.036079	3.36**	0.05604	0.014373	3.9**	0.121334	0.055405	2.19*
2008	-0.188414	0.067746	2.78**	0.003531	0.011753	0.3	0.188414	0.067746	2.07*

Table 6

The R^2 value for this model ranged from .001 to .36, which has a much wider range of correlation than the R^2 value of the TEU model. The R^2 was higher for years with high significance, such as 2006, 2007, and 2008. 1999, 2000, 2004, and 2005 have a negative relationship between initial and final size, but were not significant. In general, initial size has a positive relationship with final size. The same conclusions about the relationship, such as percentage elasticity's, hold for Portualia since the exact same model was run on this dataset.

Another method I explored was a method of Weighted Least Squares that uses Cook's Distance to determine the weight given to each data point.[7] If the Cook's Distance for that point exceeds one, that point is given a weight of zero. I used this type of Weighted Least Squares in Portualia due to the variability in growth rates for small ports and the numerous outliers that can be seen in the below figure.

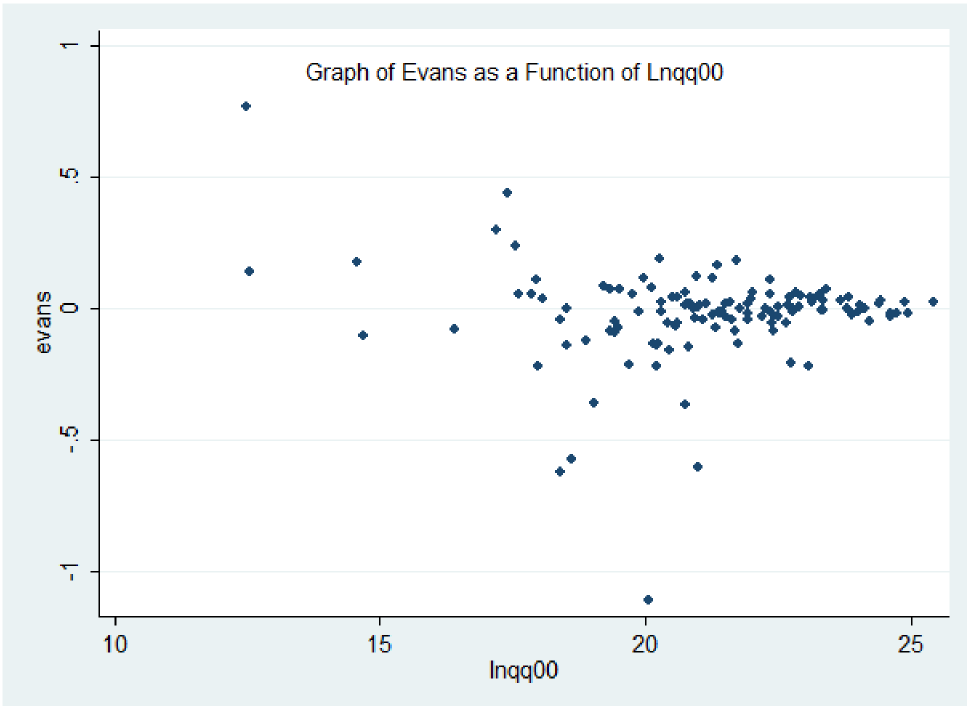

Figure 4

The physical characteristics coefficient was never significant for any of the years so was also dropped.[8] I estimate two new models with the large ports and small ports to see if Evans and Audretsch's conclusions on the relation of time interval and size hold true. The model is estimated with Equation 1 also.

[7] This is the rreg command in Stata

[8] The results of the model including physical characteristics is included in the appendix

Year	Portualia Untreated coefficient for $Size_t$	Standard Deviation	t	Robust Coefficient for $Size_t$	Robust St. Dev.	t
1991	-0.02319	0.009493	-2.44**	-0.02319	0.00876	-2.65**
1995	-0.030030	0.01258	-2.39**	-0.030030	0.009404	-3.19**
1999	0.025691	0.02514	1.02	0.025691	0.018423	1.39
2000	-0.043304	0.014173	-3.06	0.000241	0.003168	0.08
2001	0.045915	0.02096	-2.19	-0.00241	0.004684	-0.51
2002	-0.065064	0.03102	-2.10	-0.06506	0.03393	-1.92*
2003	-0.005802	0.02468	-0.24	-0.00580	0.01987	-0.29
2004	-0.100709	0.03952	-2.55**	-0.100709	0.048897	-2.06**
2005	-0.019240	0.05631	-0.34	-0.01924	0.05792	-0.33
2006	-0.17840	0.05194	-3.39**	-0.175840	0.041551	-4.23***
2007	-0.22387	0.05671	-3.95***	-0.22387	0.075524	-2.96**
2008	-0.55412	0.15513	-3.57**	-0.55412	0.09427	-5.88***

Table 7- Small Ports

Year	Portualia Untreated coefficient for $Size_t$	Standard Deviation	t	Robust Coefficient for $Size_t$	Robust St. Dev.	t
1991	-0.02685	0.0039478	-6.80***	-0.02685	0.00932	-2.88**
1995	-0.05439	0.00614	-8.86***	-0.05439	0.008298	-6.55***
1999	-0.08403	0.00893	-9.40***	-0.08403	.01736	-4.84***
2000	-0.02580	0.00581	-4.44***	0.000241	0.003168	0.08
2001	-0.05186	0.007511	0.08	-0.00241	0.004684	-0.51
2002	-0.06584	0.01060	-6.21***	-0.06584	0.01278	-5.15
2003	-0.08827	0.01162	-7.59	-0.08827	0.01582	-5.58***
2004	-0.18226	0.01376	-13.25***	-0.18226	0.0178	-10.24***
2005	-0.16199	0.02141	-7.56***	-0.16199	0.0438	-3.69***
2006	-0.30547	0.01591	-19.20***	-0.30547	0.02618	-11.67***
2007	-0.34528	0.03809	-9.07***	-0.34528	0.046903	-7.36***
2008	-0.56607	0.08137	-6.96***	-0.56607	0.14604	-3.88***

Table 8 – Large Ports

From the two tables, it is clear that size has a negative relationship with both size and the time interval. In 1991 and 2008, the coefficients for initial size are nearly the same in both tables. The coefficient for large ports is more significant and has a lower standard of error, which indicates less variability in growth rates and less outliers. I did not use Weighted Least Squares estimate because nearly all the results were significant.

The R^2 for small ports ranged from .2 to .5 and for large ports, the range was .4 to .8795. The model is better fitting for large ports and can explain up to 88% of the data.

The conclusion of each dataset is the same. Overall, ports do not obey Gibrat's Law, with size and growth rate having a negative relationship. Although Evans and Audretsch's conclusions on firm size and time intervals are relevant, only the firm size conclusion holds for ports. Given the limited years the data was measured, the long run hypothesis cannot be tested. But, the trend seems to show that in the long run, the growth rate for large ports is closer to zero than in the short run.[9]

[9] A model with physical characteristics is included in the appendix.

Conclusion

Ports are an integral part to international and national trade. The negative relationship of growth rate and initial size shows that the U.S. could increase the total trade each year by investing in smaller ports to increase their capacity, but this growth rate cannot be sustained over the long run. The study also concludes that physical characteristics are insignificant in explaining the average growth rate.

With the completion of the Panama Canal expansion, more large ships will be able to pass through, which will place more pressure on large and small ports to be able to service these. Port Authority in Miami have invested $2 billion into improving its port, involving plans on dredging and putting in $1 billion in connecting the port with the Interstate high way (U.S. Army Corps of Engineers, 2012). On the other hand, if the addition of Panama Canal to ports that can accommodate New Panamax size ships, then another potential outcome is that U.S. ports become intermediary ports or ports that serve Panamax ships or New Panamax ships avoiding congestion. Smaller ports have a higher growth rate and should also be expanded in the short run, while opening up more terminals and ports to private investment. If large ports specialize in large ships and small ports with small ships, the overall amount of trade increases. The U.S. can thus capture a larger share of the trade market.

Taking this study one step further the importance of the trade network for port facility should be tested. Although having the right physical and structural characteristics is extremely important, it is also equally important that the network to transports these goods across the country are in good condition also. This also can put more focus on how to allocate money for improving transportation of goods. Should money be allocated towards improving ports, or focused on improving the network of transportation within the U.S.? The improvement of the Panama Canal will change the market structure of international trade, shipping, and flows. Before, the Port of Los Angeles and the Port of Long Island could handle the containerized ships too large for the Panama Canal (U.S. Army Corps of Engineers, 2012). With the expansion, using these ports to transport across the Americas will no longer be economical. This brings into question the future of the U.S. in international trade. Hopefully this study brings to light how to increase the growth rate of U.S. ports so that ports can continue competing in demand for ships.

Appendix

Since I mention using physical attributes as an independent variable in the model, and do not show the results with physical characteristics, this section is to show the results with the appearance of independent variables. The characteristics will first be directly put in the model, and then with instrumental variables.

The physical characteristics chosen were ones that could prevent service to large ships, such as channel depth, cargo pier depth, and maximum vessel size. Another factor was how much capacity a port had to facilitate goods, such as number of cranes and storage space. Only one variable is used to attempt to raise the significance of the physical characteristics coefficient.

Year	**Untreated coefficient for $Size_t$**	**Standard Deviation**	**t**
2007	0.0400	0.0425	0.94
2008	-0.0547	0.0567	0.96
2009	0.0384	0.0625	0.62
2010	0.1202	0.1008	1.19
2011	0.0588	0.1032	0.57

Table 1 – Model using instrumental variables[10]

[10] The choice of instrumental variable was cargo pier depth. Cargo Pier Depth was chosen because after regressing Size on cargo pier depth, channel depth, and maximum vessel size, only cargo pier depth was significant.

Year	Untreated coefficient for Size$_t$	Standard Deviation	t	Coefficient for Channel Depth	Standard Deviation	t
2007	-0.02174	0.0107	-2.02	-.1380	0.1081	-1.28
2008	-0.04401	0.0132	-3.33**	-0.3944	0.1583	-2.49**
2009	-0.04215	0.0147	-2.87**	-0.0307	0.0147	-0.18
2010	-0.02990	0.0232	-1.28	-0.3667	0.2411	-1.52
2011	-0.00676	0.0332	0.20	0.5148	0.3568	1.44

Table 2 - Model with PC as independent variable

None of the models involving physical characteristics show any significance, except for 2009 in Table 10. Part of the lack of significance could be that Size is already affected by these physical characteristics, along with other factors, that could cause two results: one, lack of significance of the physical characteristic coefficient, and two, these other factors have a stronger effect on size than physical characteristics thus instrumental variables is not effective. Thus, overall, physical characteristics was dropped as a variable. There is no doubt that some physical attributes could affect the growth rate, but when testing with Gibrat's Law, the initial size variable captures these effects.

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