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Expansion of the Panama Canal: Effect of Transportation Cost on Bilateral Trade for USA and East Asian Partner Countries (China, Japan & South Korea)

Jonathan Loo
School of Economics, Shanghai University, Shang Da Lu 99, Shanghai, China

Abstract
When people heard Panama Canal, they usually think of a major historic engineering in the history of humanity which allows maritime vessels to transit through America from one ocean to another. A little know the influence of this infrastructure in the economic field, more over the Expansion Program which started to operate in June of 2016.The motivation of this study is to analyze the macroeconomic effect of the Expansion and its competitiveness. First the Panama Canal is of extreme importance to 5% of the total world trade and most of them comes from the East Asia-East USA maritime route, to evaluate the macroeconomic changes, the study is focused on this specific maritime route among 4 of the top users of the Panama Canal which are United State of America, China, Japan and South Korea. Second the Expansion is designed to lower Transportation Cost by applying economy in scale for bigger vessels, to carry more for each voyage and therefore reduce the time and fuel consumed.With all this approach, Gravity Model of International Trade was chosen to determine the variables which affect Bilateral Trades among these countries, the variables considered are Economic Size represented as GDP, Market Size represented as Population, Exchange Rate in United States Dollar and lastly the Distance represented as Transportation Cost. The result will not only help these countries to make strategic planning for trading but also help the Panama Canal to promote International Trade.It is important to mention that in the original Gravity Model proposed by Tinbergen in 1962 use Distance as a factor to measure bilateral trade, because the Expansion is to lower Transportation Cost, in this study we are going to calculate Transportation Cost comparing it with alternative routes such as the top competitor Suez Canal, Cape Horn and Cape of Good Hope. The result will help us to get a better insight of the Gravity Model by replacing Distance for Transportation Cost for a more accurate result; also show how competitive is the Expanded Panama Canal in the maritime market for the East Asia-East USA route. By analyzing the changes between sailing time, voyage cost, route alternatives and the possible macroeconomics effects of the expansion by comparing different scenarios focusing on opportunity cost through a pricing model. The model is designed to estimate the possible outcome of each voyage taking into consideration some of the main variables like distance, fuel, Canal dues to evaluate the estimated time comparing it to different scenarios.The result for Bilateral Trade for USA and Partner Countries shows that variables like Economic Size have a positive impact on trade which is as expected for the development of the economy, Transportation Cost is negative because the increase in transportation cost would discourage the trading among countries while the other variables show no level of significance for Trading between these countries. Transportation Cost also show an increase in effectiveness of double the amount compared to the Original Canal, also compared to other alternative routes it only have a slight advantage in term of lower cost comparison, therefore it clearly show the importance for this project to be taken in order to maintain its competitiveness in the East Asia- East USA maritime market.
Keywords: Expanded Panama Canal, Gravity Model, Transportation Cost.

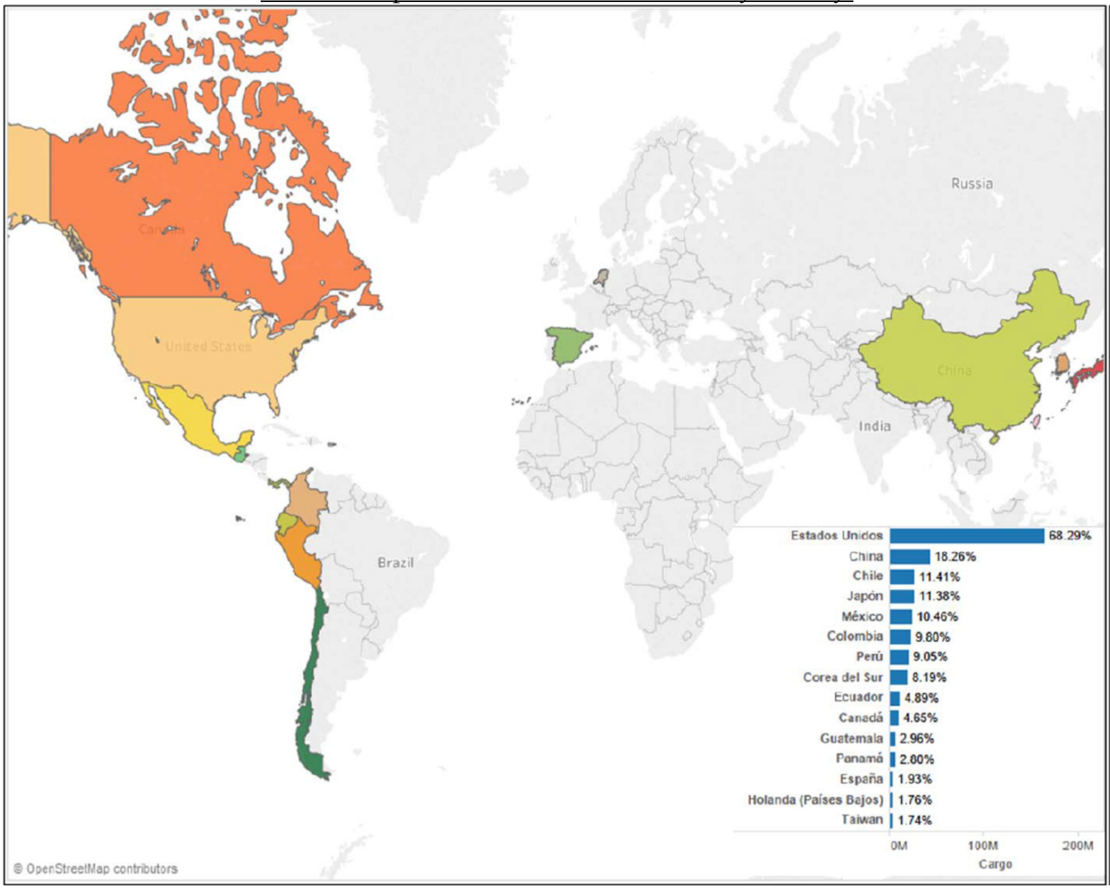
1. Background of Study

The motivation of this study is to show the competitiveness of the expanded Panama Canal to know whether or not this is the best choice for international trading and the factors which affect bilateral trade among the users. Because of its geographic positioning in the center of America, it is certain that the Panama Canal really help shorten the transit time across the Pacific and Atlantic Oceans. Since not every country made the most out of this passage based on their geographic positioning and many other factors which affect international trading, we are going to analyze the most transited maritime route and the countries which are involved.

With a great understanding of the Panama Canal and its function on the global maritime market, it is clear the expansion itself would cause a major effect on the macroeconomic situation of the global economy but there is not much evidence of these effects because the Expansion happened not long ago in June of 2016 and all the data collected is by far until 2017. This study is focused on these macroeconomic changes assuming that the Panama Canal Expansion is designed to allow bigger vessels to transit through the Canal and therefore economy in scale is applied, Transportation Cost would be the key factor for this research as to compare the changes from before and after the Expansion including other alternative routes to determine its competitiveness.

By looking at Figure3, statistic collected from the ACP by the year of 2017, United State of America is by far the most influential country of the Panama Canal with 68.2% among the main user of the Panama Canal, most of the transit happen to be East Asia-East USA traffic. From the top Asian Countries there is China with 18.2% as the second in ranking, Japan and South Korea with 11.3% and 8.1% respectively. It is also worth to mention that from statistic of 2015 and 2016, USA and China is always the first in their names from maritime traffic in the Panama Canal.

Picture3. Top 15 user of the Panama Canal by Country.



Source: Panama Canal Authorities, Transit Statistic, 2017.

By analyzing these data, we can therefore assume that the most influential maritime route of that go through the Panama Canal is that of East Asia-East USA shown in Picture4. Generally a container vessel will not go directly from its departure point to its destination, they will take a large amoung of time reaching various port loading and unloading until the container reach its destination, it is said that a vessel have its designated maritime route in which travel in circle, like the one shown in Picture4 where go from China, Japan and South Korea to East of USA. This system is designed to be cost efficient and therefore encourage bilateral Trading among these countries. In this Study we are going to focus on this specific maritime route as it has the most influential percentage on the Panama Canal.

Picture4. Maritime Route of the Study

Source: ACP, Expansion Plan, 2006

Now that we are clear on the focus of the study, some assumptions are needed to be made. First the objective of the Expansion is to generate economy in scale by saving transportation cost, to show these macroeconomic changes we are going to analyze it competitiveness by calculating the transportation cost compared with other alternative routes like the Suez Canal, Cape Horn and Cape of Good Hope. The result should show how competitive is the Expanded Panama Canal in the maritime market with actual data. Second the bilateral trade from East Asia-East USA is by far the most influential route for the Panama Canal; it would be nice to determine the variables which affect the Bilateral Trade between these countries, so for the purpose of the study four countries are chosen USA, China, Japan and South Korea. The result should show the variables with high significance level for USA and Asia Countries for strategic planning which are beneficial for these countries and the Panama Canal to promote International Trade.

Following this assumption we can separate this research into the following steps; first, we are going to look into the current situation of the Panama Canal, by analyzing the expansion program along with its influence on the Panama`s economy to understand the magnitude of this project and the cost for this operation to be undertaken; second, collect updated data and related information to calculate the transportation cost which is one of the main variables for the gravity model calculation, since the main purpose for the program is to lower transportations cost, we are going to compare it to different scenarios and alternative routes like the Suez Canal, Cape Horn and Cape of Good Hope to show its competitiveness in the maritime market; and lastly, determine the variables which are significant on the bilateral trade for USA and partner countries, the influence of these variables and the effect of lower transportation cost on bilateral trade after the expansion.

The result of this study will not only help the USA and partner countries to improve bilateral trading but also benefic the Panama Canal to make strategic planning to promote International Trading for other users as well knowing the importance of economy in scale and therefore better position the Canal in the maritime shipping market.

2. Literature Review

2.1 Related Theories and Studies

Bilateral Trade Factors

The Gravity Model of International Trade was first proposed by Jan Tinbergen (1962), with simple used formulas which evaluate trade flow using GDP of both countries and the distance between them. The formula became so popular that economist used it to explain trade flow between countries that have no comparative advantage and cannot be solved by other economic theories. In recent research a variation of the original formula was found by many studies like Rahman (2003), where he included variables like common language and openness to determine the competitiveness of Australia with other 50 countries, in his result shows that the trade flow of Australia is affected by the economic size, common language, GDP and the distance between them; or that of Dinh Thi Thanh (2011), with more variables like culture, population and exchange rate to identify the potential grow of Vietnam, the result are explained with economic size of foreign country, exchange rate, GDP of both countries and a negative distance differentiation.

The Gravity Model has also been used to test the effectiveness of Trade Agreements like the North American

Free Trade Agreement or World Trade Organization. It can also be used with many others variables as migration, foreign direct investment and traffic. It shows that apart from GDP and Distance, the bilateral trade flow can also be explained by other factors like the economic size, exchange rate, culture and common language. In this research the trade flow is between United State of America and its East Asian Partner (China, Japan and South Korea), since every country speak a different language and East Asian Countries are similar in culture in term of religion, these variables wasn't considered for this study. Variables that could be positive in relation with the bilateral trade flow of this specific maritime route are GDP, economic size in population, and exchange rate while distance in term of transportation cost will be affected negatively.

Peter Drysdale, Yiping Huang and K.P. Kalirajan (2012) in their research China`s Trade Efficiency: Measurement and Determinant using stochastic gravity model approach was applied to a cross-section bilateral trade data set containing 57 countries using the average trade flows and other variable values for the period of 1991-1995. The result was average trade efficiency for China was not only lower than that for the East Asian economies as a group but also below the average of the whole sample and inefficiency may partly be removed through appropriate policy reform. Also, an increase in overall economic freedom which includes a lower level of trade taxes is helpful to improvement in trade efficiency. A freer economic environment in China's trade partners is also favorable for higher trade efficiency for China.

Mohsen Bahmani-Oskooee and Zohre Ardalani (2006), Exchange Rate Sensitivity of U.S. Trade Flows: Evidence from Industry Data, estimated import and export value as well as volume models with monthly import and export data from 66 industries in the United States over the January 1991-August 2002 period, the result show that in the long run real depreciation of the dollar stimulates export earnings of many U.S. industries, whereas it has no significant impact on most importing industries. Using significant coefficient estimates obtained for the real exchange rate in import and export value models, showed that 10% real depreciation of the dollar improves the U.S. trade balance by 7.9%.

Huiwen Lai and Susan Chun Zhu (2004), The Determinants of Bilateral Trade, developed a monopolistic competition model that takes into account asymmetric trade barriers and international differences in production costs. The model implies a highly non-linear bilateral trade equation allowing the estimation of parameters, the elasticity of substitution and trade costs. Estimated result allowed to assess the impact of the 1992 worldwide tariff structure, elimination of these tariffs would raise world trade by 3.7% and the trade liberalization would shift trade from rich countries to poor countries and from local preferential trading areas to intercontinental trading partners.

Jon Haveman and David Hummels (2004), Alternative Hypotheses and the Volume of Trade: The Gravity Equation and the Extent of Specialization demonstrated that the gravity equation as a statistical relationship can be generated from a model with incomplete specialization. Also, that the explanation for why the gravity equation works has considerable relevance for how the gravity equation is interpreted and used and how we view bilateral trade. The results provide some insights into the extent of specialization, in that gravity equations cannot be regarded as arising only from complete specialization and that corollary evidence is highly problematic for complete specialization models.

Yong Seok Choi and Pravin Krishna (2004), The Factor Content of Bilateral Trade: An Empirical Test, the study used OECD production and trade data to test the restrictions derived by Helpman (1984) on the factor content of trade flows that hold even under none equalization of factor prices and in the absence of any assumptions regarding consumer preferences. The results are quite robust to the factor price measures used and to a variety of assumptions made in the construction of necessary variables from observed data and were unable to reject the restrictions implied by the theory for the vast majority of country pairs.

Steven S. Zahniser, Daniel Pick, Greg Pompelli and Mark J. Gehlhar (2002), Regionalism in the Western Hemisphere and Its Impact on U.S. Agricultural Exports: A Gravity Model Analysis, the gravity models in their research highlight several important developments in the pattern of U.S. agricultural exports. First, exports to Mexico during 1989-1999 were significantly higher. Second, the additional trade benefits secured by NAFTA appear to be less important to U.S. agricultural exports, providing stimulus only to grapes, yarn and thread, leather, and tobacco products. But the models do suggest that agricultural exports to Brazil may have suffered some trade diversion due to MERCOSUR. The result obtained at the aggregate level for milk and cream, legumes, and wheat. Among these commodities, wheat was the most likely case of trade diversion, as Argentina has dramatically increased its share of the Brazilian wheat market.

Md. Ghulam Rabbany, Mohammad Tanjimul Islam and Abdullah Ishak Khan (2013), Bilateral and International Trade of Bangladesh and India: Effect of Falling Exchange Rate of Indian Rupee, analyses how a currency rate of one country can reign over international trade of another country, as the bilateral trade is negative with India both countries should be aware about the future impact of their bilateral and international trade as Bangladesh has a fast growing economy it will not feel the result rapidly. Also India has current account deficiency; as a result they are facing the falling exchange rate of their currency. If rupee continues to decrease its value it can be a matter of damage for the neighboring competitors. As the export sector of Bangladesh is same it will be less competitive in the world market as India will provide the goods in a cheaper rate. The products, Bangladesh imports from India are highly price sensitive. Bangladesh will import more and India will try to reduce its import cost more.

Transportation Cost Models

Notteboom and Carriou (2009), developed a fuel consumption model, which calculate the average amount to fuel depending on the size of the vessel and the TEU capacity. In this model was a comparison of the dimension of existing container vessels from 2000 TEU to 10000 plus TEU, they evaluated the vessels engine and the amount of Fuel needed for the determined speed in maritime knots, it is obvious that larger vessels can go with higher speed but would consume more fuel. The results show that while the container ship is bigger, its consumption will be higher in proportion to its size, but the difference isn't proportional, as the amount that can be carried in TEU is not equivalent to that of smaller vessels. Which means that bigger vessels have engine that can produce the same result which is cost efficiently.

When it comes to Canal fees, Notteboom and Rodrigues (2011), they made a chart model to calculate the tolls for the Suez Canal based on the vessels weight, this model isn't an accurate method as it doesn't specify the type of vessels and the shipping products. Its purpose is for an easy way to calculate the tolls for Suez Canal to facilitate future studies, this model is used quite often by economist of the shipping industries because the model is convenient and shows and estimated amount close to the original one with and error of less than 5% depending on the dimensions of the vessels. The results goes from vessels with 3000 TEU to up to 18,000 TEU, where the ships pay 73.80 USD and 47.32 USD respectively, this clearly shows that bigger ships have the advantage of cost efficiency by allowing them to carry more container with minimum price. It is also important to mention that unlike that Panama Canal, the Suez Canal is a sea level channel which means that there is no limitation towards the weight that the Canal can handle.

Transportation Cost can be calculated with different methods but a more accurate research by Thomas Brevik and Christoffer Melleby (2014), they designed a model to calculate voyage cost more efficiently with useful variables like, fuel cost, terminal handling charges and canal fees. The model can be used with any maritime route as long as the shipping ship information is accurate from its weight to its engine power. The only down side to this models is the operation cost for the crew members, as the author say that every shipping have a more complex organization because a vessel doesn't go directly to its destination, it will actually transit from port to port loading and unloading containers making the calculation different for each shipping. The result is a model which user can input the detailed data of a container vessel choosing the maritime route and its revenue; it will determine the voyage result along with the cost for each operation.

D. Ronen (2011), The Effect of Oil Price on Containership Speed and Fleet Size, analyzed the relationship among bunker fuel price, sailing speed, service frequency and the number of vessels operating on a container line route, and devised a procedure that facilitates the determination of the sailing speed, cycle time, and number of vessels that minimize the annual operating cost of the route. The result is a cost model and the associated procedure for finding the minimal cost speed that are applicable to any liner with constant service frequency.

K. Fagerholt, G. Laporte and I. Norstad (2010), Reducing Fuel Emissions by Optimizing Speed on Shipping Routes, they developed a model for fuel optimization and the result solved the problem of determining optimal speeds along a shipping route, where each port call has a given time window, in which the service must start. As fuel consumption is typically a cubic function of speed within certain speed limits, the optimal speed problem becomes a non-linear problem where the arrival time within the time window of each node is discretized and the problem then is solved as a shortest path problem on a directed acyclic graph.

H.J. Kim (2014), Lagrangian Heuristic for Determining the Speed and Bunkering Port of a Ship, this study has considered the problem of determining the ship speed, bunkering ports, and bunkering amount at the ports with restricted bunker tank capacity. Variable ship speed was considered to represent the real situation closely with the objective of minimizing the total cost of bunker purchase, ship time, and carbon tax. The test result demonstrated the capability of the heuristic algorithm to generate near-optimal solutions for practically sized problems within a short time despite a slight sensitivity to the costs.

E. Kozan and B. Casey (2007), Alternative Algorithms for the Optimization of a Simulation Model of a Multimodal Container Terminal, developed a model for export and import container process in multi-modal terminals to investigate the minimum ship delays. The model is very complex due to the fact that they consist of multiple areas that require careful synchronization between the various container transfer nodes. It also summarizes the results that are obtained from tests of a number of solution techniques such as Genetic Algorithm and Tabu Search, which are used to solve a benchmark problem of the model.

Jane Korinek and Patricia Sourdin (2010), Clarifying Trade Costs: Maritime Transport and Its Effect on Agricultural Trade, analyses maritime transport costs and the importance of shipping in determining agricultural trade flows. The cost of shipping represented 10% of the overall cost of importing goods world- wide in 2007, and maritime transport costs are even higher for some products, the cost of importing grains has also risen sharply in some cases by 250% between 2003 and 2007. The result is that increases in transport costs negatively impact trade flows in almost all products, but particularly impact trade in some products exported by developing countries like cereals and sugar.

When evaluation this kind of research, it is common to find information all over the area because is a large topic with a lot of aspect to cover. Most of them explain scenarios as prediction or possibilities, but these explanations are not supported with statistical data because of the many unknown variables.

2.2 Theoretical Framework & Research Hypotheses

The expansion of the Panama Canal is a major engineering project of the Republic of Panama; it is of my interest to analyze the possible macroeconomic effect that is game changing for the republic. In this study we are focusing on one of the most transited maritime route that uses that Panama Canal, East of United State to East Asia Countries China, Japan and South Korea. According to statistic of the ACP, this maritime route account for more than 70% of the total transit in 2017. We are going to analyze the bilateral trade flow of these countries using data obtained from International Trade Centre, World Bank and http://www.x-rates.com for Exchange Rate.

Since the beginning of economy all the classical theory indicate that a country should produce goods with absolute advantage and trade with countries that are less similar to obtain the benefit of International Trade but all of these theories doesn’t explain why countries why no advantage still trade with others. Through recent studies found that countries trading can be influenced by many different variables, like the distance, common language, border frontier, currencies and much more.

To get a better idea of the variables that are influential on bilateral trade for United States of America and partner East Asian Countries, we are going to use the Gravity Model of International Trade but instead of the original formula, additional variables are included like Population as market size, Exchange Rate for each countries and Transportation Cost as distance.

With a variation of the original Gravity Model, the main difference is the variable distance, as we are going to calculate it as transportation cost, because the Expansion of the Panama Canal is to allow economy in scale and exploit the efficiency of big vessels by transporting more products in a single voyage. In order to calculate the Transportation Cost, we are going to use the Model developed by Thomas Brevik and Christofer Melleby (2014) for voyage cost. I find this model very useful and accurate for study of the maritime industry. Altogether with data calculation for the Transportation Cost from others author like the Fuel Consumption Model of Notteboom and Carriou and Suez Canal Model from Rodrigues.

<u>Original Gravity Model of International Trade proposed by Jan Tinbergen in 1962</u>

$$F_{ij} = G\frac{M_i * M_j}{D_{ij}}$$

Distance=Transportation Cost when it comes to International Trade

F is trade flow between country i and j
G is a constant
M is masses of country i and j (usually represented as GDP)
D is distance from country i to j

The calculation for this model used in this study is a variation with additional variables Population to represent the market size of United State and Partner Countries, Exchange Rate set to 1.00 US Dollar for partner countries and Transportation Cost to represent the distance between these countries, the study is goning to be first with the transportation cost for the original Canal and second with the transportation cost for the expanded Canal. This method is to compared the outcome and changes done by the Expansion. The equation will be as follow in logarithm variables. Note that the transportation cost should be negative as the more is the cost the less likely is for the country to trade. Devaluation of Partner currency may cause a negative effect on the trading.

<u>For Original Canal Transportation Cost</u>

$Log(TF_{upt})=\beta_0+\beta_1 log(GDP_{ut})+\beta_2 log(GDP_{pt})+\beta_3 log(Pop_{ut})+\beta_4 log(Pop_{pt})+\beta_5 log(TC_{oc})+\beta_6 log(ER_{upt})+\mu$

<u>For Expanded Panama Canal Transportation Cost</u>

$Log(TF_{upt})=\beta_0+\beta_1 log(GDP_{ut})+\beta_2 log(GDP_{pt})+\beta_3 log(Pop_{ut})+\beta_4 log(Pop_{pt})+\beta_5 log(TC_{ec})+\beta_6 log(ER_{upt})+\mu$

The only difference between both formulas is the transportation cost, the first one is that transportation cost without the expansion and the second one is after the expansion. The variables for this gravity model can be explained as the following table.

Table5. Variables Explanation

u	United State
p	China, Japan, South Korea
t	2008-2016
oc	Original Canal
ec	Expanded Canal
TF_{upt}	Bilateral Trade Flow of USA with Partner in year t
GDP_{ut}	USA GDP in year t
GDP_{pt}	Partner GDP in year t
Pop_{ut}	USA population in year t
Pop_{pt}	Partner population in year t
TC_{ec}	Transportation Cost for Expanded Canal
TC_{oc}	Transportation Cost for Original Canal
ER_{upt}	Exchange Rate between USA and Partner in year t
μ	Error Term

Also the following hypothesis can be deducted based on this framework.

Hypothesis1 Economic size should cause a positive effect
Hypothesis2 Market Size should cause a positive effect
Hypothesis3 Transportation Cost should cause a negative effect
Hypothesis4 Exchange Rate should cause a positive effect

To the best of my knowledge there isn't a single paper debating the bilateral trade flow of United State in this particular maritime route through the Panama Canal with China, Japan or South Korea. Because the expansion happened not long time ago, available data may not be enough to explain the result of these macroeconomic effects. Some variables like common language, migration, religion, culture and port infrastructure were not considered as it is irrelevant to this study. Transportation Cost was considered instead of Distance because it can give more accurate result as higher distance don't necessarily means less trade, it can be influenced by many other variables like that of Terminal Handling Charges or vessel capacity.

3. Transportation Cost Comparison

A voyage model is developed using Thomas Brevik and Christoffer Melleby (2014) study for Shipping Market Model with a focus on alternative cost. Because of the scarcity of resources, the best way to compare the competitiveness of the Panama Canal would be establishing different scenario using the same starting point and destination for each route alternative. The main focus of this research is to show the impact of the expanded Panama Canal over the world trading shipping industry. Note, all the data are calculated using Excel 2010.

Ship Information

Two container ships were chosen for the purpose of this study, the first one is the Maersk Taurus capable of 8500 TEU with speed of 25 knots, and second one is the Maruba Cristina of 2500 TEU with 22 knots speed. Both are vessels capable of going through the Panama Canal, being Pospanamax and Panamax respectively.

Table6. Container Ships Information.

Ships	TEU	Speed in knots
MARUBA Cristina (Panamax)	3500	22
Maersk Taurus (Postpanamax)	8500	25

Source: http://www.containership-info.com/

Time Charter Equivalent

Time Charter Equivalent or TCE is a standard measurement for shipping performance. This information will be used to measure the effectiveness of the vessels performance after the Expansion of the Panama Canal. A standard method to calculate TCE is to divide voyage revenues by available days for the relevant time period. Expenses primarily consist of port, canal and fuel costs.

3.1 Data Analysis

3.1.1 Distance from Port to Port

These distances are found using the link https://sea-distances.org/. Which show in nautical miles de distances from the Asian Port to the Port of NY/NJ through the different alternative routes.

Table7. Sea Distance in Nautical Miles for USA and Partner Countries.

From	To	Route	Sea Distance in Nautical Miles
Port of Yokohama	Port of NY/NJ	Panama Canal	9698
Japan	United State	Suez Canal	13025
		Cape Horn	16240
		Cape of Good Hope	15120
Port of Busan	Port of NY/NJ	Panama Canal	10085
South Korea	United State	Suez Canal	12636
		Cape Horn	16647
		Cape of Good Hope	14737
Port of Shanghai	Port of NY/NJ	Panama Canal	10582
China	United State	Suez Canal	12370
		Cape Horn	16746
		Cape of Good Hope	14468

Source: https://sea-distances.org/

This information is crucial for this model, needed for calculation of time spend during operation depending on the vessels capacity, also the analysis of this model is based on single voyage transportation cost, and to determine the fastest route to its destination.

3.1.2 Time at Sea

The following formula is to determine the time in days that the vessel spend at the sea. The time spend at port will be calculated with another formula. A 5% is added for unforeseen factor like weather condition, urgent emergency, and engine problem, among other.

$$Ts = \frac{\frac{D}{V}}{24} + 5\%$$

Ts Total travelling time in days
D Distance travelled in nautical miles
V Speed of the vessel in knots
24 Hours to get time in days
5% Unforeseen Factors

Table8. Time spend at Sea by days for each scenarios.

Destination: Port NY/NJ	MARUBA Cristina	Maersk Taurus	Maersk Taurus	Maersk Taurus	Maersk Taurus
	Panama Canal Before Expansion	Panama Canal After Expansion	Suez Canal	Cape Horn	Cape of Good Hope
Yokohama Port	19.28	16.97	22.79	28.42	26.46
Port of Busan	20.05	17.64	22.11	29.13	25.78
Port of Shanghai	21.04	18.51	21.64	29.3	25.31

Source: Calculated by Author

As seen in this comparison for the different routes, the shortest is through the Panama Canal after the Expansion. These numbers are expresses in days, for the first row a different vessel is used for the calculation as the Maersk Taurus wasn't able to travel in the original canal. The purpose of this comparison is to evaluate the exploitation of larger vessels after the expansion for reduced cost.

3.1.3 Time in Port

Additional data was needed to calculate the time in ports, some of the variables that are taking into considerations are the amount of cargo the vessels are shipping and the efficiency of the port to move those container. A Port Productivity Report was developed by Journal of Commerce in 2013 where they analyze the productivity of the port for moving containers, Container Move per Vessel per hour or MVP, the data are shown as following. 78 MPV for NY/NJ Port, 105 MPV for Busan Port, 104 MPV for Shanghai Port, 108 MPV for Yokohama Port, 88 MPV Hong Kong Port

$$Tp = \frac{L}{P * 24}$$

Same formula is used for loading port and unloading port

Tp Time in Port
L Container Loaded and Unloaded (TEU carried)
P Berth Productivity per hour (MVP)
24 hours to get time in days

Table9. Time spend in Ports by Days for each scenarios.

Destination:	MARUBA	Maersk
Port NY/NJ	Cristina	Taurus
TEU carried	3000	8000
Yokohama Port	2.75	7.35
Port of Busan	2.79	7.44
Port of Shanghai	2.8	7.47

Source: Calculated by Author

Represented in total days spend in ports, the result is the summary of loading and unloading, Asian ports and destination NY/NJ port. As the maximum capability for each vessel are 8500 and 3500 TEU respectively. Just for the purpose of the research they are assumed to carry 8000 and 3000 TEU.

3.1.4 Fuel Cost

While the fuel prices may go from 400.00 to 600.00 dollars per tons according to https://shipandbunker.com/prices#IFO380. Notteboom and Carriou (2009) developed a fuel consumption model, which calculate the average amount to fuel depending on the size of the vessel and the TEU capacity. See table below.

Table10. Fuel Consumption for container vessels.

	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000	8000-9000	9000-10000	10000+	Total #
Number of vessels #	764	350	469	285	146	60	122	46	17	2259
Mean size (TEU)	2530	3432	4385	5491	6505	7372	8293	9307	11660	4332
Mean design speed (nm) - v_0	21.2	22.4	23.9	24.5	25.3	25.1	24.9	25.1	23.6	23.04
Mean age (year)	10.1	11.6	6.5	5.2	4.4	4.7	1.9	1.4	0.6	7.8
Mean main engine (kW)	20699	26741	38616	49243	57764	61436	64353	67259	66580	36084
Engine type										
- Two Stroke/Slow speed (%)	93	98	99	97	99	98	99	100	100	2184
- Other *(a)* (%)	7	2	1	3	1	2	1	0	0	75
Fuel consumption in tonnes/day *(b)*	80	102	142	199	229	233	255	N/A	N/A	121
Fuel consumption in grams//teu/mile	62	55	56	62	58	52	51	N/A	N/A	0.000051
	Estimations on fuel consumption at sea for various speed									
FC_{mi1} **in tonnes/day *(c)***	**78.1**	**106.4**	**136.4**	**171.3**	**203.4**	**230**	**260**	**292**	**367 *(d)***	**134.8**
Vessel speed (knots)										
18	47.0	54.9	52.8	57.9	68.8	77.8	87.9	98.8	124.1	66.0
19	56.1	65.6	63.1	69.3	82.2	93.0	105.1	118.1	148.4	78.9
20	66.5	77.7	74.7	82.0	97.4	110.1	124.5	139.8	175.7	93.5
21	**78.1**	91.3	87.8	96.4	114.4	129.4	146.2	164.2	206.4	109.8
22	-	**106.4**	102.4	112.3	133.4	150.8	170.5	191.5	240.7	128.0
23	-	-	118.5	130.1	154.5	174.7	197.5	221.8	278.7	**148.3**
24	-	-	**136.4**	149.7	177.8	201.0	227.2	255.2	320.7	-
25	-	-	-	**171.3**	**203.4**	**230.0**	**260.0**	**292.0**	**367.0**	-

(a) Not Specified

(b) HFO consumption is only available for the main engine and for 594 observations.

(c) Estimation from equation (4) for main engine and at the mean size in TEU and design speed v0 of the category.

(d) Due to the limited number of observations for vessels more than 10,000 TEU (17 vessels), we assume that the design speed for this category is 25 knots (Man B&W Diesel A/s, 2008)

Source: Fuel Consumption Model, Notteboom and Carriou (2009)

To calculate the Fuel Cost is quite complicated because every operation of the shipment ships are different, to solve this just assume the ships have their engine off while at port and therefore no fuel is consumed. A 5% additional margin is added for unpredicted event and just to make sure the container ship doesn't arrive at its destination with empty fuel. The formula is as follow.

$$FC = (Ts * F) + 5\%$$

FC Fuel Cost
Ts Time at Sea

F Fuel Consumption (according to the table)

Table11. Fuel Consumed in tonnes per day for each scenarios.

Destination: Port NY/NJ	MARUBA Cristina	Maersk Taurus	Maersk Taurus	Maersk Taurus	Maersk Taurus
	22 knots	25 knots	25 knots	25 knots	25 knots
	Panama Canal Before Expansion	Panama Canal After Expansion	Suez Canal	Cape Horn	Cape of Good Hope
Yokohama Port	2153.96	4632.81	6221.67	7758.66	7223.58
Port of Busan	2239.98	4815.72	6036.03	7952.49	7037.94
Port of Shanghai	2350.58	5053.23	5907.72	7998.9	6909.63

Source: Calculated by Author

The table 11 shows the amount of fuel consumed using the formula for fuel cost in tonnes per day. The fuel for Maruba Cristina can be quite low due to its capacity and size compared to the Maersk Taurus but because of the container capacity the Taurus have higher revenue.

After knowing the amount that each ship consumes for these alternative routes, it is time to calculate the total cost in dollars. In this case the fuel cost per tonnes can be set to 500.00 dollars just for comparison of the study, because the prices may differ from country to country. These prices are shown in the table 10.

Table12. Amount in Dollars for Fuel Consumed for each scenarios.

Destination: Port NY/NJ	MARUBA Cristina	Maersk Taurus	Maersk Taurus	Maersk Taurus	Maersk Taurus
	22 knots	25 knots	25 knots	25 knots	25 knots
	Panama Canal Before Expansion	Panama Canal After Expansion	Suez Canal	Cape Horn	Cape of Good Hope
Yokohama Port	$ 1,076,980.00	$ 2,316,405.00	$ 3,110,835.00	$ 3,879,330.00	$ 3,611,790.00
Port of Busan	$ 1,119,990.00	$ 2,407,860.00	$ 3,018,015.00	$ 3,976,245.00	$ 3,518,970.00
Port of Shanghai	$ 1,175,290.00	$ 2,526,615.00	$ 2,953,860.00	$ 3,999,450.00	$ 3,454,815.00

Source: Calculated by Author

3.1.5 Terminal Handling Charges

To calculate the handling charges for each port, the European Commission (2009) made a report for each of the most rated port from each country, although these numbers are not specific and may be different depending on the shipment ship. The reports are based on average rates on TEU of the vessel capacity and are shown in their country currency.

Table13. Terminal Handling Charges proposed by European Commission, 2009.

Port	Pre-October 2008	Post-October 2008		
	Average Rate	**Average Rate**	**Range**	**Currency**
New York & New Jersey	460	507	390-803	USD
Shanghai	964	681	465-1403	CNY
Busan	118,000	123,257	117,500-180,000	KRW
Yokohama	34,737	32,163	13,750-40,000	JPY

Source: European Commission (2009), THC table 23 and 26

Because the terminal handling charges shown in their report are not in dollars, a currency converter from https://finance.yahoo.com/currency-converter/ for each port.

Note the route THC are the summary of departure port plus destination port.

Table14. THC for each scenario in their local currency.

Local Currency	MARUBA Cristina	Maersk Taurus	
Port NY/NJ	1774500.00	4309500.00	USD
Yokohama Port	112570500.00	273385500.00	JPY
Port of Busan	431399500.00	1047684500.00	KRW
Port of Shanghai	2383500.00	5788500.00	CNY

Source: Calculated by Author

Table 14 shows the THC in their country currency for each container ships and the table 13 are the conversion in United State Dollars.

Table15. THC for each scenario converted to USD.

Currency Conversion	United State Dollars	MARUBA Cristina	Maersk Taurus
	Port NY/NJ	$ 1,774,500.00	$ 4,309,500.00
1JPY=0.0094USD	Yokohama Port	$ 1,058,162.70	$ 2,569,823.70
1KRW=0.001USD	Port of Busan	$ 431,399.50	$ 1,047,684.50
1CNY=0.1606USD	Port of Shanghai	$ 382,790.10	$ 929,633.10

Source: Calculated by Author

The formula to calculate the THC is as below.

Total THC = Departure port THC + Destination port THC

Table16. Total THC calculated for Transportation Cost in USD.

Destination: Port NY/NJ	MARUBA Cristina	Maersk Taurus
Yokohama Port	$ 2,832,662.70	$ 6,879,323.70
Port of Busan	$ 2,205,899.50	$ 5,357,184.50
Port of Shanghai	$ 2,157,290.10	$ 5,239,133.10

Source: Calculated by Author

3.1.6 Canal Fee

Panama Canal

Actually the ACP have a website calculator for tolls charges transit per TEU found in their official website http://www.pancanal.com/ basically can be described as following.

- 74 dollars per vessel capacity
- 8 dollars per container TEU
- 65.60 dollars for ballast transit per vessel capacity (without cargo)

Because the Panama Canal has its limit to the weight that it can handle, 74 per TEU of the vessel total capacity plus 8 per TEU of its cargo are charged before transiting into the Canal and 65.60 per vessel weight in TEU is charged when the ship has no cargo.

Table17. Panama Canal tolls for the determined vessels in Dollar.

	MARUBA Cristina	ACP fees		Maersk Taurus	ACP fees
Capacity TEU	3500	$ 259,000.00		8500	$ 629,000.00
Cargo TEU	3000	$ 24,000.00		8000	$ 64,000.00
Total tolls		$ 283,000.00			$ 693,000.00

Source: Calculated by Author

As shown in the comparison the Maersk Taurus has more than double of the cargo of that of Cristina, but the Canal fees is just slightly higher, this explains the economy in scale based on cargo amount. For the study of this model, both tolls are added to see the difference of that before and after the Panama Canal Expansion for Maruba Cristina and Maersk Taurus respectively.

Suez Canal

The Suez Canal also offer a website calculator for the tolls for its service, but unlike the Panama Canal, Suez Canal has no limitation toward the size of the vessel as it is a sea level Canal and allow container ships of any size to go through it which is a competitive factor compared to the Panama Canal. However the fee calculation can also be done more easily based on a model presented by Notteboom & Rodrigues back in 2011, because the tolls are charged toward vessel capacity, the cargo is excluded from the calculation.

Table18. Measurement to calculate Suez Canal tolls

TEU-capacity	Typical SCNT*	Canal transit fees	Net tonnage fee	Fee on-deck containers	Per TEU average	
3 000	30 659	$ 221 403	$ 205 002	$ 16 400	$ 73,80	
4 000	41 625	$ 271 939	$ 251 796	$ 20 144	$ 67,98	
6 000	63 557	$ 373 589	$ 339 627	$ 33 963	$ 62,26	
8 000	85 489	$ 455 770	$ 414 336	$ 41 434	$ 56,97	
10 000	107 421	$ 536 782	$ 483 588	$ 53 195	$ 53,68	
13 000	140 319	$ 654 455	$ 584 335	$ 70 120	$ 50,34	
18 000	-	$ 851 798	-	-	$ 47,32	**

*Suez Canal Net Tonnage = 10,966 x TEU-capacity - 2238,7 (R-square = 0,9861)

**Based on an average decline in cost per TEU-average from 8 000 to 10 000 TEU and 10 000 to 13 000 TEU of approximately 6 %

Source: Notteboom & Rodrigues (2011), Suez Canal Fees

Table19. Suez Canal Tolls for each vessels in USD

	MARUBA Cristina	Suez Canal Fees		Maersk Taurus	Suez Canal Fees
Capacity TEU	3500	73.8 per TEU		8500	56.97 por TEU
Total tolls		$ 258,300.00			$ 484,245.00

Source: Calculated by Author

Compared to the Panama Canal, the tolls are slightly lower when the size of the vessel is small, on the other hand for Maersk Taurus the difference is much more visible almost 30% less for more than double the cargo, which means if the container ship is much larger it can benefit more from the revenue and because the Suez Canal is a sea level canal, the largest vessel can benefit even more from its scale in economic term.

3.2 Transportation Cost Comparison Model

The main objective behind this Model is to see the effect of the Panama Canal Expansion to the World economy by comparing each of the different situations. TCH is often used by companies to see the revenue of a vessel operation as explained in the beginning of this model.

Table20. Transportation Cost Comparison with Alternative Routes.

Destination: Port NY/NJ	MARUBA Cristina Panama Canal Before Expansion	Maersk Taurus Panama Canal After Expansion	Maersk Taurus Suez Canal	Maersk Taurus Cape Horn	Maersk Taurus Cape of Good Hope
Yokohama Port					
Fuel Cost	$ 1,076,980.00	$ 2,316,405.00	$ 3,110,835.00	$ 3,879,330.00	$ 3,611,790.00
Terminal Handling Charges	$ 2,832,662.70	$ 6,879,323.70	$ 6,879,323.70	$ 6,879,323.70	$ 6,879,323.70
Canal Fees	$ 283,000.00	$ 693,000.00	$ 484,245.00		
Total Transportation Cost	$ 4,192,642.70	$ 9,888,728.70	$ 10,474,403.70	$ 10,758,653.70	$ 10,491,113.70
Gross Revenue	$ 4,500,000.00	$ 12,000,000.00	$ 12,000,000.00	$ 12,000,000.00	$ 12,000,000.00
Voyage Result	$ 307,357.30	$ 2,111,271.30	$ 1,525,596.30	$ 1,241,346.30	$ 1,508,886.30
Time Charter Equivalent	$ 13,951.76	$ 86,812.14	$ 50,617.00	$ 34,703.56	$ 44,628.40
Port of Busan					
Fuel Cost	$ 1,119,990.00	$ 2,407,860.00	$ 3,018,015.00	$ 3,976,245.00	$ 3,518,970.00
Terminal Handling Charges	$ 2,205,899.50	$ 5,357,184.50	$ 5,357,184.50	$ 5,357,184.50	$ 5,357,184.50
Canal Fees	$ 283,000.00	$ 693,000.00	$ 484,245.00		
Total Transportation Cost	$ 3,608,889.50	$ 8,458,044.50	$ 8,859,444.50	$ 9,333,429.50	$ 8,876,154.50
Gross Revenue	$ 4,500,000.00	$ 12,000,000.00	$ 12,000,000.00	$ 12,000,000.00	$ 12,000,000.00
Voyage Result	$ 891,110.50	$ 3,541,955.50	$ 3,140,555.50	$ 2,666,570.50	$ 3,123,845.50
Time Charter Equivalent	$ 39,015.35	$ 141,226.30	$ 106,279.37	$ 72,916.89	$ 94,035.08
Port of Shanghai					
Fuel Cost	$ 1,175,290.00	$ 2,526,615.00	$ 2,953,860.00	$ 3,999,450.00	$ 3,454,815.00
Terminal Handling Charges	$ 2,157,290.10	$ 5,239,133.10	$ 5,239,133.10	$ 5,239,133.10	$ 5,239,133.10
Canal Fees	$ 283,000.00	$ 693,000.00	$ 484,245.00		
Total Transportation Cost	$ 3,615,580.10	$ 8,458,748.10	$ 8,677,238.10	$ 9,238,583.10	$ 8,693,948.10
Gross Revenue	$ 4,500,000.00	$ 12,000,000.00	$ 12,000,000.00	$ 12,000,000.00	$ 12,000,000.00
Voyage Result	$ 884,419.90	$ 3,541,251.90	$ 3,322,761.90	$ 2,761,416.90	$ 3,306,051.90
Time Charter Equivalent	$ 37,098.15	$ 136,306.85	$ 114,145.03	$ 75,099.73	$ 100,855.76

Source: Calculated by Author

As shown in the result, the transportation cost can be quite different when used as a variable compared to distance, the example of Japan the transportation cost is actually higher in comparison with China, while China is way farter to the United State but its THC is lower than that of Japan, also South Korea which is closer in distance represent almost the same result compared to China.

3.2.1 Gross Revenue

The gross revenue is complicated to calculate it depends on the products that are being shipped. Just for the purpose of the study the gross revenue is set to be 1500 dollars per TEU carried to just have a general idea of the effect of the expansion.

Table21. Proposed Gross Revenue in Dollar.

	MARUBA Cristina	Suez Canal Fees		Maersk Taurus	Suez Canal Fees
Cargo	3000	1500 per TEU		8000	1500 per TEU
Revenue		B/. 4,500,000.00			B/. 12,000,000.00

Source: Calculated by Author

3.2.2 Total days in Operation

Is the summary of total days at sea plus days spent in port. This information is used to calculate the Time Charter Equivalent.

Table22. Total Days in Operation for each scenarios.

Destination: Port NY/NJ	MARUBA Cristina	Maersk Taurus	Maersk Taurus	Maersk Taurus	Maersk Taurus
	Panama Canal Before Expansion	Panama Canal After Expansion	Suez Canal	Cape Horn	Cape of Good Hope
Yokohama Port	22.03	24.32	30.14	35.77	33.81
Port of Busan	22.84	25.08	29.55	36.57	33.22
Port of Shanghai	23.84	25.98	29.11	36.77	32.78

Source: Calculated by Author

3.2.3 Comparison of Time Charter Equivalent for each Alternative Route

This is calculated by dividing the Voyage Result with the amount of days spend in operation. To identify the revenue for each operational days.

$$TCE = \frac{Voyage\ Result}{Total\ Days\ in\ Operation}$$

Table23. Time Charter Equivalent for each scenario in Dollar.

Destination: Port NY/NJ	MARUBA Cristina	Maersk Taurus	Maersk Taurus	Maersk Taurus	Maersk Taurus
	Panama Canal Before Expansion	Panama Canal After Expansion	Suez Canal	Cape Horn	Cape of Good Hope
Yokohama Port	$ 13,951.76	$ 86,812.14	$ 50,617.00	$ 34,703.56	$ 44,628.40
Port of Busan	$ 39,015.35	$ 141,226.30	$ 106,279.37	$ 72,916.89	$ 94,035.08
Port of Shanghai	$ 37,098.15	$ 136,306.85	$ 114,145.03	$ 75,099.73	$ 100,855.76

Source: Calculated by Author

3.3 Result Analysis

After analyzing every aspect of the scenarios as seen in the model, the effect of the Panama Canal Expansion is massive. Using the Maersk Taurus as example it get the highest revenue if it goes through the expanded Panama Canal, the difference is 30% more income in term of Cost saving with exception of the port in Hong Kong because of its geographic position which is closer to de Suez Canal.

By comparing the alternative routes we can see that although paying a Canal fee can benefit from time saving and therefore generate more revenue. Prior to the expansion looking at the Maruba Cristina, there is no way to compare the amount of money saved by implementing larger vessels can be 4 times lower compared to the large vessel going with a longer route.

The efficiency in Shanghai Port and Busan Port is outstandingly amazing, plus the THC is way cheaper in these two ports that encourage more trading between these two countries around the world, this is one of the reasons why China and South Korea are exporting more.

With this study it is clear to see the competitiveness of the Panama Canal, if these changes weren't made, the revenue for world trade among Panama Canal user is so low that eventually will companies will chose to take an alternative route instead of using the Panama Canal.

Because of the limitation of the Panama Canal, its mechanic of rising and lowering the vessels, make it so difficult to be competitive among maritime routes, eventually will reach its maximum capacity again and future planning would need to be make to keep its value in the International Market.

4. Bilateral Trade Flow Analysis

In this section we are going to look for the variables that are relevant to the trade flow of United State of America with Japan, South Korea and China. By applying Gravity Model of International Trade with a variation of the original formula proposed by Tinbergen in 1962. Some of the additional variables considered in this model are Market Size of United State and Partner Countries represented by the Population of these countries to determine the relation of it with trade flow of US; the Exchange Rate of Partner countries in relationship with the US Dollar all set to 1.00 equivalent USD for Partner local currency (Japanese Yen, South Korean Won and Chinese Yuan) and lastly the Transportation Cost calculated in the previous Model to replace the Distance in the Original Gravity Equation, this is because the Transportation Cost can actually show a more precise number in comparison to Distance as many other variables can influence in the Transportation Cost for Container Shipping.

4.1 Variables Explanation

4.1.1 Bilateral Trade Flow (Import and Export)

The Data is found in the International Trade Centre (www.intracen.org) for the Import and Export of United State in relationship with partner countries. This would be the dependent variable for the study, the summary of Import and Export is the Bilateral Trade for these countries.

Table24. Bilateral Trade Flow for USA and Partner Countries in USD, 2008-2016.

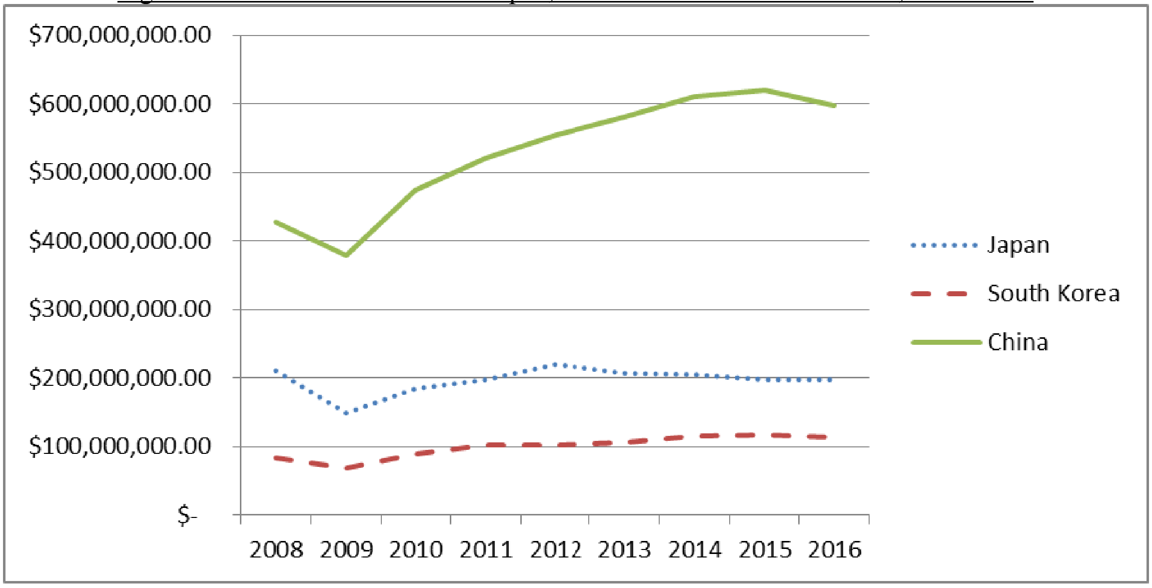
	United State Import and Export to Japan		
Year	Export	Import	Trade Flow
2008	$66,573,422.00	$ 143,351,759.00	$ 209,925,181.00
2009	$51,178,320.00	$ 98,401,031.00	$ 149,579,351.00
2010	$60,469,046.00	$ 123,762,733.00	$ 184,231,779.00
2011	$65,791,777.00	$ 132,558,803.00	$ 198,350,580.00
2012	$69,971,995.00	$ 150,447,023.00	$ 220,419,018.00
2013	$65,213,790.00	$ 142,136,718.00	$ 207,350,508.00
2014	$66,825,973.00	$ 137,503,838.00	$ 204,329,811.00
2015	$62,441,250.00	$ 135,023,800.00	$ 197,465,050.00
2016	$63,234,270.00	$ 135,116,983.00	$ 198,351,253.00

	United State Import and Export to South Korea		
Year	Export	Import	Trade Flow
2008	$ 34,806,587.00	$ 49,823,394.00	$ 84,629,981.00
2009	$ 28,639,748.00	$ 40,543,872.00	$ 69,183,620.00
2010	$ 38,820,633.00	$ 50,607,876.00	$ 89,428,509.00
2011	$ 43,461,394.00	$ 58,605,754.00	$ 102,067,148.00
2012	$ 42,282,529.00	$ 60,997,693.00	$ 103,280,222.00
2013	$ 41,686,042.00	$ 64,611,252.00	$ 106,297,294.00
2014	$ 44,470,809.00	$ 71,745,454.00	$ 116,216,263.00
2015	$ 43,444,787.00	$ 74,045,678.00	$ 117,490,465.00
2016	$ 42,308,097.00	$ 71,881,139.00	$ 114,189,236.00

	United State Import and Export to China		
Year	Export	Import	Trade Flow
2008	$ 71,456,412.00	$356,304,561.00	$427,760,973.00
2009	$ 69,575,613.00	$309,530,233.00	$379,105,846.00
2010	$ 91,910,977.00	$382,964,820.00	$474,875,797.00
2011	$ 104,121,383.00	$417,340,262.00	$521,461,645.00
2012	$ 110,516,536.00	$444,386,004.00	$554,902,540.00
2013	$ 121,721,076.00	$459,107,864.00	$580,828,940.00
2014	$ 123,675,623.00	$486,296,238.00	$609,971,861.00
2015	$ 116,071,709.00	$504,028,117.00	$620,099,826.00
2016	$ 115,602,060.00	$481,516,030.00	$597,118,090.00

Source: International Trade Centre

Figure5. Trade Flow of USA with Japan, South Korea and China in USD, 2008-2016.



Source: International Trade Centre

The Trade Flow was greatly affected in the year of 2009 because of the Economic crisis but is recovered in the following year, as we can see in the chart above the trading between United State and China is six and tree time higher compared to that of South Korea and Japan respectively. Reasons why China, Japan and South Korea are among the main user of the Panama Canal, according to statistic of the ACP in 2017, China represent 18.26% of the total shipment in the Panama Canal along with 11.38% for Japan and 8.19% for South Korea.

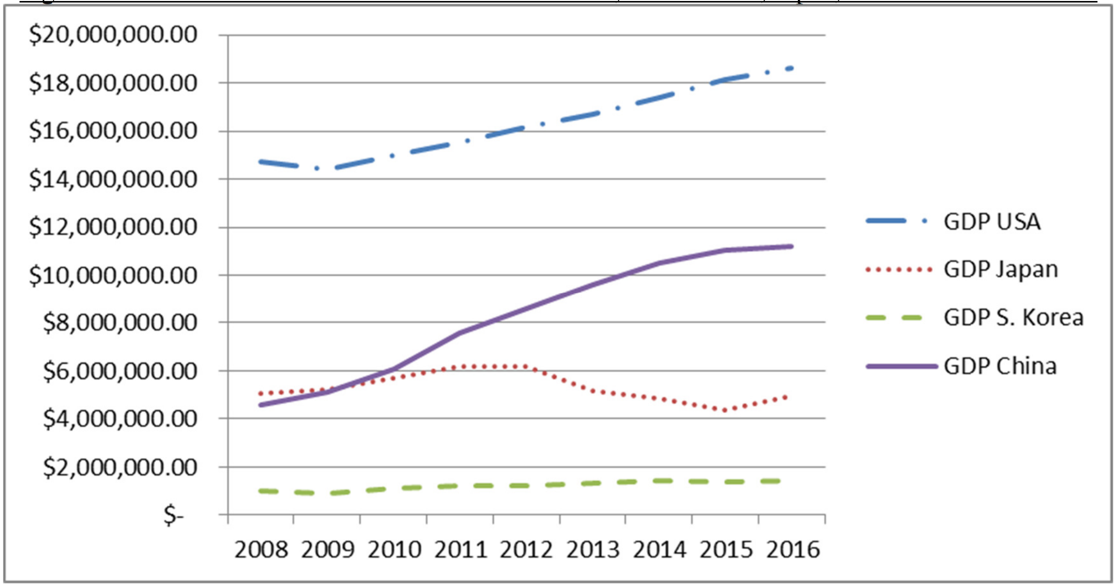
4.1.2 GDP of United Sate, Japan, South Korea and China (Economic Size)

Table25. GDP in thousands of Dollar of United Sate, Japan, South Korea and China 2008-2016

Year	GDP USA	GDP Japan	GDP S. Korea	GDP China
2008	$ 14,718,582.00	$ 5,037,908.47	$ 1,002,219.05	$ 4,598,206.09
2009	$ 14,418,739.00	$ 5,231,382.67	$ 901,934.95	$ 5,109,953.61
2010	$ 14,964,372.00	$ 5,700,098.11	$ 1,094,499.34	$ 6,100,620.49
2011	$ 15,517,926.00	$ 6,157,459.59	$ 1,202,463.68	$ 7,572,553.84
2012	$ 16,155,255.00	$ 6,203,213.12	$ 1,222,807.28	$ 8,560,547.31
2013	$ 16,691,517.00	$ 5,155,717.06	$ 1,305,604.98	$ 9,607,224.48
2014	$ 17,393,103.00	$ 4,848,733.42	$ 1,411,333.93	$ 10,482,372.11
2015	$ 18,120,714.00	$ 4,383,076.30	$ 1,382,764.03	$ 11,064,666.28
2016	$ 18,624,475.00	$ 4,940,158.78	$ 1,411,245.59	$ 11,199,145.16

Source: World Bank

Figure6. GDP in thousands of dollar from 2008 to 2016, United State, Japan, South Korea and China



Source: World Bank

The data was extracted from the World Bank (data.worldbank.org) the amount is represented in thousands of dollar. As we all know the economy in South Korea isn't growing much and it keeps a steady pace while Japan is constantly influenced by natural disaster but the culture itself is pretty much keeping the economy going. China reached an increase of almost double the amount during the years of 2010 to 2015 considered the fasted growing economy in East Asia but the government is changing the policy toward service instead of low labor manufacture in recent years.

4.1.3 Population of United Sate, Japan, South Korea and China (Market Size)

Table26. Population in thousands of people of United Sate, Japan, South Korea and China from 2008-2016.

Year	Pop. USA	Pop. Japan	Pop. S.Korea	Pop. China
2008	304093.97	128063	49054.71	1324655
2009	306771.53	128047	49307.83	1331260
2010	309348.19	128070	49554.11	1337705
2011	311663.36	127833	49936.64	1344130
2012	313998.38	127629	50199.85	1350695
2013	316204.91	127445	50428.89	1357380
2014	318563.46	127276	50746.66	1364270
2015	320896.62	127141	51014.95	1371220
2016	323127.51	126994.51	51245.71	1378665

Source: World Bank

The data was also extracted from the World Bank (data.worldbank.org) in thousands of people. This data is to represent the Market Size for each market, with an increase in population the consumption will also increase. The result should be positive toward the trade flow as an independent variable.

4.1.4 Transportation Cost from United State to East Asian Partner Countries

Distance is represented as Transportation Cost in International Trade. In this study we are going to evaluate the effect with the Expansion of the Panama Canal, assuming two different cases, the first one with variables obtained from previous model for Original Canal and the second is after the Expansion. The data can be resumed as follow.

Table27. Transportation Cost set to 1 TEU in USD.

Distance	No Expansion	After Expansion
Japan to US	1397.54	1236.09
S.Korea to US	1202.96	1057.25
China to US	1205.19	1057.34
Amount in US Dollar per TEU carried		

Source: Calculated by Author from previous Transportation Cost Model

4.1.5 Exchange Rate for Japan, South Korea and China

Table28. Exchange Rate set to 1.00 USD for Japan, South Korea and China, 2008-2016.

Year	Japanese Yen	South Korea Won	Chinese Yuan
2008	108.043301	942.160467	7.2486
2009	90.43154	1348.993477	6.835948
2010	91.335959	1142.151858	6.827892
2011	82.515232	1119.213169	6.597156
2012	76.961445	1142.824278	6.314987
2013	89.101486	1064.945616	6.22409
2014	103.9994	1065.459481	6.050715
2015	118.422379	1088.661511	6.217631
2016	118.483507	1201.450913	6.56281
Value set to 1.00 USD for corresponding year			

Source: http://www.x-rates.com

Based on previous studies made by Dinh Thi Thanh Binh in 2011 shows that Exchange Rate on Gravity Model can help explain the trade variation amongs participating countries. An increase in Exchange Rate means that partner local currency is devaluated and therefore export to the United State will increase and import will decrease.

4.2 Bilateral Trade Analysis using Gravity Model

As mentioned before this study will compare two different regressions to see the result obtained from these additional variables. The Model is done by STATA incorporating the logarithm form of each of the selected variables as follow.

Dependent Variable Trade Flow

Independent Variables GDP, Population, Transportation Cost and Exchange Rate

Data is obtained from the previous section and transformed into logarithm form using STATA and the description can be explained as table29.

Table29. Variables descriptions.

Variable	Description
TF_{upt}	USA trade with partner countries
GDP_{ut}	GDP of USA
GDP_{pt}	GDP of China, Japan and South Korea
Pop_{ut}	Population of USA
Pop_{pt}	Population of China, Japan and South Korea
TC_{oc}	Transportation Cost for Original Canal
TC_{ec}	Transportation Cost for Expanded Canal
ER_{upt}	Exchange Rate of USA with partner countries

Table30. Variables in logarithm form generated in STATA.

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
TF_{upt}	*27*	*19.19248*	*.7121003*	*18.05227*	*20.24539*
GDP_{ut}	*27*	*16.60218*	*.0891243*	*16.48404*	*16.73999*
GDP_{pt}	*27*	*15.11818*	*.8513657*	*13.7123*	*16.23135*
Pop_{ut}	*27*	*12.65649*	*.0197918*	*12.62509*	*12.6858*
Pop_{pt}	*27*	*12.23202*	*1.412329*	*10.80069*	*14.13663*
TC_{oc}	*27*	*7.143134*	*.0715827*	*7.09254*	*7.242469*
TC_{ec}	*27*	*7.015549*	*.075055*	*6.963427*	*7.119709*
ER_{upt}	*27*	*4.489466*	*2.143323*	*1.800177*	*7.207114*

For Original Canal Transportation Cost

Table31. Model Specification for Original Canal.

Dependent Variable: TF_{upt} R^2=0.9913

Independent Variable	*Coef.*	*Std. Err.*	*t*	*P>/t/*
GDP_{ut}	*2.193796*	*.8275471*	*2.65*	*0.015*
GDP_{pt}	*.3436874*	*.1182014*	*2.91*	*0.009*
Pop_{ut}	*-6.396353*	*3.852603*	*-1.66*	*0.112*
Pop_{pt}	*.098831*	*.2590256*	*0.38*	*0.707*
ER_{upt}	*-.1352879*	*.1900245*	*-0.71*	*0.485*
TC_{oc}	*-1.669629*	*.9988086*	*-1.67*	*0.110*
_cons	*69.85496*	*37.06131*	*1.88*	*0.074*

After running the regression for the first time, we can see the variable Pop_{pt} and ER_{upt} have a very high level of insignificance in relation with Trade Flow 70% and 48%; therefore we exclude these two variables and run the regression again. Also it shows that these variables can explain 99% of the Trade Flow looking at R^2.

Table32. Model Specification after excluding insignificant variables.

Dependent Variable: TF_{upt} R^2=0.9791

Independent Variable	*Coef.*	*Std. Err.*	*t*	*P>/t/*
GDP_{ut}	*2.677388*	*1.211549*	*2.21*	*0.038*
GDP_{pt}	*.86878*	*.0275846*	*31.50*	*0.000*
Pop_{ut}	*-12.20366*	*5.463892*	*-2.23*	*0.036*
TC_{oc}	*-4.145483*	*.3236506*	*-12.81*	*0.000*
_cons	*145.6748*	*49.71774*	*2.93*	*0.008*

After running the second regression, the result isn't as expected. By looking at R^2 the difference isn't much compare to previous regression which explains the level of significance of these variables from 99% to 97%. The variables which have influence on United State and East Asian Countries bilateral Trade Flow are: Economic size of US and Partner (US and ASIA GDP), United State Market Size (US Population) and Transportation Cost (Before Expansion). The variables GDP_{ut} and Pop_{ut} also show an insignificance of 3.8% and 3.6% respectively. The result can be presented as follow.

$$TF_{upt} \quad =145.67+2.67(GDP_{ut})+0.86(GDP_{pt})+-12.20(Pop_{ut}) +-4.14(TC_{oc})+\mu$$

GDP grow of United State and Partner Countries which represent Economic Size have a positive effect, increase in 1% of United State GDP will enhance 2.67% of bilateral Trade Flow and the same for 1% increase in Partner GDP will enhance 0.86 of bilateral Trade Flow. Therefore Hipothesis1 is strongly supported to be positive, with increase in economic size and bilateral trade flow between US and Partner Countries. Transportation Cost support Hypothesis4 with a negative effect on bilateral Trade Flow, increase in 1% of Transportation Cost will reduce the bilateral Trade Flow by -4.14%.

For Market Size as population with an increase in 1% US population will actually lower the bilateral Trade Flow by -12.20% and Partner population show a high level of insignificance of 70%. Therefore we can reject the Hypothesis2 for an insignificance of 5% level. The result isn't as expected based on previous research the market size should promote bilateral trade between countries. As for Hypothesis3 we can also reject with a 5% level because the Exchange Rate showed a total insignificant level of 48% toward the bilateral Trade Flow.

For Expanded Panama Canal Transportation Cost

Table33. Model Specification for Expanded Canal.

Dependent Variable: TF_{upt} R^2=0.9913

Independent Variable	*Coef.*	*Std. Err.*	*t*	*P>/t/*
GDP_{ut}	*2.193823*	*.8275531*	*2.65*	*0.015*
GDP_{pt}	*.3437302*	*.1182006*	*2.91*	*0.009*
Pop_{ut}	*-6.396421*	*3.852622*	*-1.66*	*0.112*
Pop_{pt}	*.0979575*	*.2594967*	*0.38*	*0.710*
ER_{upt}	*-.1352567*	*.1900138*	*-0.71*	*0.485*
TC_{ec}	*-1.596448*	*.9550603*	*-1.67*	*0.110*
_cons	*69.13884*	*36.91517*	*1.87*	*0.076*

Again Pop_{pt} and ER_{upt} show a high level of insignificance of 71% and 48% respectively. They are removed from the regression.

Table34. Model Specification after excluding insignificant variables.

Dependent Variable: TF_{upt} R^2=0.9793

Independent Variable	*Coef.*	*Std. Err.*	*t*	*P>/t/*
GDP_{ut}	*2.673212*	*1.205908*	*2.22*	*0.037*
GDP_{pt}	*.8651083*	*.0273654*	*31.61*	*0.000*
Pop_{ut}	*-12.15967*	*5.438397*	*-2.24*	*0.036*
TC_{oc}	*-3.943066*	*.3062239*	*-12.88*	*0.000*
_cons	*143.294*	*49.47414*	*2.90*	*0.008*

With similar result as before and a R^2 of 97%, we can assume the equation to be the same with improved coefficient.

$$TF_{upt} = 143.29+2.67(GDP_{ut})+0.86(GDP_{pt})+-12.15(Pop_{ut})+-3.94(TC_{ec})+\mu$$

4.3 Result Analysis

The same result can be applied for the second regression, with increase in 1% of US GDP enhance bilateral Trade Flow by 2.67% and 1% increase Partner GDP enhance bilateral Trade Flow by 0.86%, supporting Hypothesis1. Transportation Cost has a different coefficient but the result is the same with 1% increase will reduce bilateral Trade Flow by -3.94% supporting Hypothesis3. While Hypothesis2 and Hypothesis4 are to be rejected at 5% level because of insignificance but US population, 1% increase in US population will decease bilateral Trade Flow by -12.15%.

After running the regression for No Panama Canal Expansion and Expanded Panama Canal, the result is the same, only difference is the coefficient of that of Transportation Cost which is lower for the Expanded Panama Canal -4.14 to -3.94, therefore it is clear to say that the Panama Canal Expansion Project is a success in lowering transportation cost in an economy in scale for bigger vessels which in turn promote trading between user countries. The variables which influence the Bilateral Trade Flow of United State of America and Partner Countries are Economic Size of both countries with a positive effect, Market Size of USA negatively and lastly Transportation Cost negatively. It is important to mention that the results are not as expected from related research because the analysis is made to a specific maritime route that uses the Panama Canal.

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