To what extent will the Panama Canal expansion lower transportation costs and enhance the competitiveness of exports from the United States?

Master of Arts in Law and Diplomacy Capstone Project

Submitted by Shelton Metcalf

April 18, 2013

http://fletcher.tufts.edu

THE FLETCHER SCHOOL

TUFTS UNIVERSITY

The Fletcher School of Law and Diplomacy

To what extent will the Panama Canal expansion lower transportation costs and enhance the competitiveness of exports from the United States?

Shelton D. Metcalf
The Fletcher School, Tufts University
Medford, MA
Shelton.Metcalf@tufts.edu
Master's Capstone Project: Research Thesis
Advisor: Professor Carsten Kowalczyk

Submitted: April 18, 2013

Introduction

The Panama Canal expansion plan, on pace to be completed in 2015, has the potential to alter international shipping routes. The $5.2 billion infrastructure project calls for building a third channel that will accommodate post-Panamax vessels, which will double the capacity limits for the canal.[1] Additionally, some specialized vessels will be able to use the Canal that previously could not. As a result, exporters, logistics experts, port authorities, vessel operators, and many others are eagerly anticipating its completion.

For the United States, the canal expansion is expected to benefit trade between the U.S. Gulf Coast and East Coast and Asian markets because using the canal significantly shortens the

[1] "Panama Canal and the Port of New Orleans Renew Strategic Alliance." Panama Canal Authority. Press Release, Aug. 8, 2011, http://www.pancanal.com/eng/pr/press-releases/2011/08/08/pr420.html (accessed October 10, 2012).

distance and transit time between these two locations. The expansion also permits the use of larger vessels that take advantage of economies of scale. In short, the improved canal is believed to reduce transportation costs for U.S. exports using this route, making U.S. export goods more competitive on the international market.

However, this outcome is not assured for many reasons. First, other shipping routes have advantages that will compete with the Panama Canal. The main, competing routes from the U.S. Gulf to Asia are through the Suez Canal and around the Cape of Good Hope (South Africa). These options are longer in distance, but they allow larger vessels than the current Panama Canal. Second, many U.S. and Asian ports have draft limitations that exclude larger vessels from entering their harbors. Any increase in these ports' drafts will take time and large financial investments. Third, the possibility of longer average transit times could counteract the benefits of the Panama Canal. From this short list of hindrances, it is inconclusive at this point whether the expanded Panama Canal will be better than the alternatives and furthermore, whether it will have a positive impact on U.S. export competitiveness.

Additionally, a key factor influencing U.S. export competitiveness via the Panama Canal expansion is the Canal toll rates. The Panama Canal Authority is keen to recoup its investment costs from the expansion project, and higher toll rates are expected. For example, one expert predicts that the fee for LNG tankers could reach as high as $1 million per transit.[2] However, it is unknown by how much, or if at all, the rates will rise.

To assess the impact of future Panama Canal on U.S. exports, this paper will first evaluate the transportation costs for select U.S. exports using the Panama Canal (based on its current toll rates) and compare them against the transportation costs using the Suez Canal and

[2] Max Gostelow, "Consultant Expects More Than $1 Million in Panama Canal LNG Fees," *Platts LNG Daily*, September 12, 2012, under "Singapore," http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Shipping/8716172 (accessed March 5, 2013).

Cape of Good Hope routes. Second, it will conduct a sensitivity analysis test that compares the derived transportation costs for each U.S. export under different Panama Canal toll fee scenarios. This test will expose how sensitive transportation costs are for each good examined to canal rates vis-à-vis alternative shipping routes.

As examples, this paper will consider U.S. exports of liquefied natural gas (LNG), wheat and medicine.[3] These goods will be transported from the U.S. Gulf Coast to Tokyo, Japan. This approach will hold constant many variables to allow cross comparisons between the routes and goods, as well as the different toll fee scenarios.

In advance of researching the topic, this paper expects to find the following outcomes: (1) the route using the expanded Panama Canal will have the lowest unit cost for transportation and lowest delivery prices for all three export goods as compared to the Suez Canal and Cape of Good Hope routes under current Panama Canal toll rates (Scenario A); (2) the same will also hold under the sensitivity analysis when toll rates equal 115% (Scenario B) and 130% (Scenario C) of current levels; (3) however, under Scenarios B and C the effect of higher toll rates will impact the competitiveness of using the Panama Canal route for LNG the most, followed by wheat, and medicine the least based on the proportional influence of transportation costs on the delivery prices of each good, which is expressed as an ad-valorem equivalent tariff; (4) therefore, this paper predicts that future toll rate hikes will result in a greater percentage decrease in the exports of LNG via the Panama Canal to Japan as compared to wheat and medicine.[4]

To test hypotheses (1)-(4), this paper will be structured as follows. Section I will provide necessary background information. It will present statistics on the three shipping routes, such as

[3] This paper examines the transportation costs for medicine based on Remodulin, a U.S. based injection drug to treat pulmonary hypertension. The drug creator and manufacturer, United Therapeutics, is in the process of distributing the drug in Japan.

[4] However, it is important to recognize that exporters do not always use the cheapest route for a variety of reasons, such as delivering cargoes to multiple destinations or changing the destination en route.

their share of total global trade, distances and vessel limitations. This section will also explain the selection of vessel types and sizes, plus the choice of LNG, wheat, and medicine as the export goods of interest.

Section II will estimate the transportation costs for each good using each shipping route based on current canal toll rates (Scenario A). It will outline the methodology used and assumptions made to set up this cost comparison. This structure will determine the unit cost for transportation for each good/route option. The lowest unit costs will identify the best route for each good.

Section III will explain the importance of transportation costs on the delivery price of a good. The economic theory and equations guiding this section will be based on the research in "Transportation Costs and Adjustments to Trade" by David Hummels.

Section IV will apply the theory in Section III to determine the delivery prices for LNG, wheat, and medicine exports using each transportation route under Scenario A.

Section V will conduct a sensitivity analysis test that will compare transportation costs under different canal fee circumstances affect the delivery prices for the three goods.

Section VI will present shortcomings in the paper. Specifically, it will identify weaknesses in the transportation costs model and the sensitivity analysis scenarios, as well as propose how future research can further the understanding of transportation costs and its link with export competitiveness.

Finally, Section VII will discuss how the transportation costs model will identify prudent policy and investment decisions for government officials, businesses and the shipping industry to pursue to enhance U.S. export competitiveness. Additionally, the sensitivity analysis results will provide guidance to Panamanian officials on how to effectively price future canal fees.

Section I: Background information

Global shipping routes

To transport exports from the U.S. Gulf Coast to Tokyo, Japan, there are three viable shipping routes: (1) through the Suez Canal, (2) around the Cape of Good Hope, or (3) through the Panama Canal. Each option has unique features that exporters and shipping lines take into account when deciding how to transport goods from the point of origin to the final delivery destination.

Figure 1 in the Appendix provides images of the three routes. The distance for each route is determined using Google Earth geospatial tools and can be found in Table 1 in the Appendix.

First, the Suez Canal is a vital shipping lane that connects the Mediterranean Sea with the Red Sea and has been so since the age of Egyptian Pharaohs.[5] Today, it accounts for approximately 8% of global trade.[6] Furthermore, the canal permits the passage of large vessels known as Suezmax vessels.

To transit from the U.S. Gulf to Tokyo, Japan through the Suez Canal, a vessel must cross the Atlantic Ocean, the Mediterranean Sea, the Suez Canal, the Red Sea, the Indian Ocean, the Malacca Straights and finally, the South China Sea. This voyage covers about 14,520 nautical miles.[7]

Second, the Cape of Good Hope has become another valuable shipping route. This is primarily because it does not limit vessel sizes. Therefore, exporters can take advantage of economies of scale by using the largest ships available.

---

[5] "Canal History," Suez Canal Authority, http://www.suezcanal.gov.eg/sc.aspx?show=8 (accessed November 3, 2012).

[6] Marianne Stigset and Gelu Sulugiuc, "Suez Canal, Carrying 8% of Trade, Open Amid Unrest," Bloomberg,http://www.bloomberg.com/news/2011-01-31/egypt-s-suez-canal-carrying-8-of-world-trade-remains-open-amid-violence.html (accessed November 3, 2012).

[7] Refer to Table 1 of the Appendix.

A voyage from the U.S. Gulf to Japan using the Cape of Good Hope route entails crossing the Atlantic Ocean around the southern tip of Africa, the Indian Ocean, and the South China Sea. It spans a distance of about 15,520 nautical miles.[8]

Third, the Panama Canal is a crucial shipping lane for U.S. imports and exports. When it opened in 1914, the canal provided an important link between the Pacific and Atlantic Oceans.[9] Approximately 5% of global trade passes through the Panama Canal each year.[10] The canal's dimensions restrict vessels to those known as Panamax vessels.

The expansion plan currently under construction will allow larger ships. According to the Panama Canal Authority (ACP), the third channel will permit maximum dimensions of "366 meters LOA, 49 meters in beam, and 15.2 meters in tropical freshwater (TFW) draft."[11] This will allow post-Panamax containerships, Suezmax liquid-bulk tankers, and Capesize dry-bulk carriers to transit the expanded canal.[12] For a general sense of vessel types and sizes, see Figure 2 in the Appendix, which presents classification definitions from Lloyd's Register.

The route from the U.S. Gulf to Tokyo through the Panama Canal involves crossing the Gulf of Mexico, transiting the Panama Canal and then crossing the Pacific Ocean. The total distance is roughly 9,133.5 nautical miles.[13]

---

[8] See Table 1 in the Appendix.
[9] "End of Construction." Panama Canal Authority. http://www.pancanal.com/eng/history/history/end.html (accessed October 10, 2012).
[10] Tim Johnson, "Widening of Panama Canal Will Remake World Trade Patterns," *McClatchy Newspapers*, August 6, 2012. http://www.mcclatchydc.com/2012/08/06/159848/widening-of-panama-canal-will.html (accessed October 10, 2012).
[11] "Dimensions for Future Lock Chambers and 'New Panamax' Vessels," Panama Canal Authority,http://www.pancanal.com/common/maritime/advisories/2009/a-02-2009.pdf (accessed October 10, 2012).
[12] *Ibid*.
[13] See Table 1 in the Appendix.

Selection of U.S. export goods

This paper will evaluate the transportation costs for three U.S. goods: liquefied natural gas (LNG), wheat and medicine, which will travel from the U.S. Gulf Coast to Tokyo, Japan. These goods have been selected for several reasons.

First, each good is shipped on specialized vessels that have unique transportation costs. The following section will elaborate on those facets further. Second, these goods differ in how they are produced and how they are priced. Therefore, these selections will produce divergent transportation costs, which will deepen the conclusions that this paper will make on the impact of the Panama Canal expansion for all U.S. exports more broadly.

Additionally, Japan is the world's largest importer of LNG, the top importer of U.S. wheat, and a major importer of medical products.[14] As a result, there is a competitive market structure to transport and price the three products in Japan. Moreover, there is reliable data on the trade volumes, prices and transportation costs between both countries.

Development of maritime vessels and transportation

There is a strong connection between world GDP growth and maritime trade. Research estimates that maritime transportation carries roughly 90% of global trade, in terms of total tonnage, and "from 1970 to 2010 the value of exports [grew] by a factor of 48 times if measured in current dollars, while GDP increased 22 times and population increased 1.8 times."[15]

A main reason for the world's reliance on ocean transportation is the specialization of maritime vessels, which have made tremendous advancements. Three main categories of vessels

[14] "Country Analysis Briefs: Japan," U.S. Energy Information Administration, June 4, 2012. http://www.eia.gov/countries/cab.cfm?fips=JA (accessed October 10, 2012); U.S. Dept. of Agriculture, Agricultural Marketing Service. *Grain Transportation Report*. January 31, 2013. http://dx.doi.org/10.9752/TS056.01-13-2013 (accessed February 2, 2013); *Top U.S. Exported Commodities to Japan in 2011*, in the UN Comtrade,http://www.comtrade.un.org (accessed March 6, 2013).

[15] Dr. Jean-Paul Rodrigue, "Transportation, Globalization and International Trade," The Geography of Transport Systems, http://people.hofstra.edu/geotrans/index.html (accessed February 13, 2013).

transport the vast majority of sea-borne trade: bulk liquids tankers, dry-bulk carriers, and container vessels.[16] In 2011, these vessel classes constituted approximately 36% of the global vessel fleet and transported 82% of world trade in gross tonnage terms.[17] Additionally, each category can be divided into sub-groups. For example, bulk liquids tankers are comprised of oil and chemical tankers, LNG tankers, and LPG tankers, to name a few. With this in mind, this paper will employ a specific vessel type under each of the three classifications to provide a comprehensive assessment of maritime transportation costs.

LNG tankers are a specific classification of bulk liquids tankers, and they have been growing in numbers and size. Currently there are an estimated 369 LNG tankers in service.[18] The largest of these vessels is Q-Max tankers, which have a total cargo capacity of 266,000 cubic meters (CM), which is enough natural gas to supply electricity to an estimated 70,000 U.S. homes for an entire year.[19]

Bulk carriers transport the vast majority of non-liquid raw commodities, such as iron ore, coal and grains. Wheat is traditionally shipped on bulk vessels with 80,000 DWT or less, which equates to a maximum of about 43,000 gross tonnes of cargo.[20] However, the trend in shipping is to move to larger, more cost effective vessels. Therefore, this paper will estimate transportation costs of wheat in larger bulk carriers than those in use today.

Unlike the other two vessel types, container vessels do not travel directly from one origin to one destination. Shipping companies instead operate liner services, which mean that a

[16] Institute for Chartered Shipbrokers, "The Reasons for Sea Transport," in*Introduction to Shipping*, 2nd ed. (Livingston, U.K.: Witherby Seamanship International, 2008), 4-5.
[17] *The World Merchant Fleet in 2011* (Equasis, 2011), http://equasis.org (accessed March 2, 2013).
[18] Michelle Wiese Bockmann, "Reshaping Panama Canal Trade Means Boom in U.s. Gas to Asia," *Bloomberg*, February 1, 2013. http://www.bloomberg.com/news/2013-02-01/reshaping-panama-canal-trade-means-boom-in-u-s-gas-flow-to-asia.html (accessed February 2, 2013).
[19] "Q-max," Maritime-Connector, http://www.maritime-connector.com/wiki/q-max(accessed March 6, 2013).
[20] These volumes are based on the bulk carrier vessel Galio, a good representation of the global wheat vessel fleet. Information about it can be found at www.marinetraffic.com

container may be transported on multiple vessels and visit several ports before it arrives at its final delivery point. For the sake of simplicity, this paper will assume that container voyages travel direct from origin to destination in order to maintain constant comparisons.

Additionally, container vessels have increased in size over time. Today's largest container ship is the CMA-CGM Marco Polo, which can transport 16,000 twenty-foot containers (TEU).[21] However, current Panamax vessels can only accommodate at most 5,000 TEUs.[22]

Section II: Estimating the unit cost of transportation

Methodology

To analyze the potential impact of the new Panama Canal on U.S. exports, this paper will develop a model to examine the transportation cost differences between using the Panama Canal, the Suez Canal and the Cape of Good Hope routes. This approach will hold constant the extraneous variables and key in on the true differences between each route. For example, two bulk cargo voyages from the U.S. Gulf to Tokyo, Japan via the Cape of Good Hope could vary greatly. The vessels could have different cargo capacities, could carry multiple goods or just one, and could call other ports along the way. Therefore, the volume of each good exported from the U.S. and the amount delivered to Tokyo would vary, as would the transit times. As a result, transportation costs would differ even though the same route was used. This model will eliminate the unwanted variation.

The Transportation Costs Model

First, this paper employs Google Earth geospatial tools to establish the total distance (in nautical miles) for each route. It assumes that every voyage makes a direct delivery from the

[21] "World's Largest Container Ship Over Time," Container Transportation,http://www.container-transportation.com/worlds-largest-container-ship.html (accessed February 6, 2013).
[22] Bill Armbruster, "Game Changer: Expansion of the Panama Canal Will Reshape Global Trade Patterns," Cargo Business News,http://www.cargobusinessnews.com/Feb10/portcomm_game_changer.html (accessed April 18, 2013).

Gulf to Japan along each designated route. It then presumes an average speed of 18 knots per hour for LNG tankers, 16 knots per hour for wheat dry-bulk carriers, and 25 knots per hour for container vessels. Additional time is allotted for transiting the Panama and Suez Canals based on their published average canal water times. As a result, one-way transit times are calculated for each vessel type along each shipping route. Tables 1, 2 and 3 of the Appendix outline the results.

Second, this paper assumes that exporters are profit maximizing and will use the largest possible vessel for each good and route. Therefore, vessel sizes are determined for each good based on the maximum physical limitations of each route. The Cape of Good Hope route is unconstrained, while the Suez Canal and Panama Canal routes have draft and width restrictions. As such, the transportation model selects appropriate vessel sizes for each good/route combination.

For LNG exports, the Suez Canal the Cape of Good Hope routes can accommodate the largest LNG tankers currently in service, Q-Max tankers, which have capacities of 266,000 CM. The Panama Canal route utilizes LNG tankers capable of carrying 200,000 cubic meters (CM) of LNG.

For wheat exports, bulk carriers of 200,000 dead weight tonnes (DWT), 150,000 DWT, and 120,000 DWT will be used for the Cape of Good Hope, Suez Canal, and Panama Canal routes, respectively. These vessel sizes can correspondingly carry approximately 155,556 MT, 116,667 MT and 93,333 MT of bulk cargo.

For medicine exports, the Suez Canal route can accommodate container vessels with 13,000 twenty-foot equivalent units (TEU), the expanded Panama Canal permits container vessels with 12,500 TEU, and the Cape of Good Hope allows the largest container vessels with 16,000 TEU. These figures are presented in Tables 4, 5 and 6 in the Appendix.

Third, Tables 7, 8 and 9 show the transportation costs under Scenario A for LNG, wheat exports and medicine, respectively. These costs include vessel chartering fees, canal transit fees, insurance rates, and import tariff rates. For example, the vessel chartering fee is $125,000/day and $14,000/day for LNG tankers and bulk carriers, respectively. All of these costs fluctuate over time, but specific values are chosen so that a cost comparison can be made.

The Unit Cost of Transportation

Now, the paper is able to determine the unit cost of transportation for each good along each route, based on current Panama Canal toll rates (Scenario A). To do so, the transportation costs shown in Tables 7, 8 and 9 are converted into a common unit of measure for each good. LNG export transportation costs are shown in million British thermal units (MmBtu) because natural gas is priced in that measurement. Similarly, wheat export transportation costs are equated in metric ton (MT) prices, and the specific medicine examined is priced per milliliter (ml).

Therefore, the unit cost of transportation for each good is simply the sum of the transportation costs in unit terms. From Table 10, the unit cost of transportation for LNG exports equals $4.63/MmBtu for the Suez Canal, $4.56/MmBtu via the Cape of Good Hope, and $4.42/MmBtu through the Panama Canal. Likewise, Table 11 indicates that it costs $70.73, $63.12, and $68.34 per MT to transport wheat exports along the Suez Canal, Cape of Good Hope and Panama Canal routes, respectively. Table 12 shows that the unit cost of transportation for medicine is $0.0297/ml for the Suez Canal, $0.0291/ml via the Cape of Good Hope, and $0.0284/ml through the Panama Canal.

Analysis of unit cost results

From the results in Tables 10, 11 and 12, it is apparent which shipping route is best for each export good. For LNG exports, the Panama Canal route supplies the lowest unit cost of transportation ($4.42/MmBtu), but the other two options are not far off ($4.56/MmBtu for the Cape of Good Hope and $4.63/MmBtu for the Suez Canal). This outcome supports the prediction stated in hypothesis (1).

The same outcome appears for medicine. Table 12 shows that the Panama Canal route delivers lowest unit of transportation ($0.0284), although the nominal price difference between the other routes is a fraction of a penny ($0.0291 for the Cape of Good Hope and $0.0297 for the Suez Canal).

However, the unit cost results for wheat exports do not confirm hypothesis (1). For wheat exports, the Cape of Good Hope route represents the lowest unit cost of transportation at $63.12/MT, while the Suez Canal and Panama Canal options equal $70.73/MT and $68.34/MT, respectively.

The differing results are due to a variety of factors. First, the vessel sizes vary more in absolute and relative terms for wheat (120,000 DWT to 200,000 DWT) than for LNG (200,000 CM to 266,000 CM) or for medicine (12,500 TEU to 16,000 TEU). This affords the Cape of Good Hope route an advantage in economies of scale that exceeds the additional costs from the longest transit time. Second, the daily charter rate for a bulk carrier ($13,000/day) is much less than for a LNG tanker ($125,000/day) or a rough equivalent charter fee for a container vessel.[23] Therefore, the additional transit time using the Cape of Good Hope route does not impact the unit cost of transportation for wheat exports as significantly as for LNG exports or medicine.

[23] This paper defines a rough equivalent charter fee for a container vessel along each route to equal the total number of TEUs/vessel, multiplied by the OFR/TEU, divided by the transit time.

Now that the unit costs of transportation for wheat, LNG and medicine exports via the three routes are established, the following section will determine the final delivery prices for each good and route combination under Scenario A.

Section III: Influence of transportation costs on delivery prices

Delivery Prices

The delivery price of a good is the total cost to deliver a good to a foreign market. It encompasses all costs, such as production, transportation and import tariffs. The difference between the delivery price and the market price for a good determines whether or not an exporter can enter that foreign market. If the delivery price is less than the market price, then the exporter can compete with domestic producers and other foreign exporters.[24] Therefore, exporters aim to obtain the lowest possible delivery price for a given market.

Transportation costs are one factor that determines the delivery price. Furthermore, changes to transportation costs can affect the delivery prices for two goods differently. This paper will assess how the difference in transportation costs between the three routes impact the delivery prices for LNG, wheat and medicine.

Transportation as an iceberg cost

According to Hummels (2012), the iceberg approach is simple and applies transportation costs as an exogenous, fixed percentage of the value shipped. Thus it acts like an ad valorem tariff on the price of the good. It is illustrated by the following equations:

(1.1) $p^* = p(1+ \tau)$, or as a ratio,

(1.2) $p^*/p = (1+ \tau)$

Where p is the origin price, p^* is the delivery price, and τ is the iceberg factor.

[24] This ignores other barriers to trade that distort market access.

From equation (1.1), Hummels explains that "iceberg costs create interesting feedback loops, as better (lower τ) access to foreign markets becomes a source of comparative advantage for firms."[25]

Additionally, the equation can be transformed to illustrate the ad valorem rate of transportation costs, as follows:

(1.3) $\tau = (p^*/p)-1$

Here, equation (1.3) illustrates how greater iceberg costs (higher τ) exemplify a larger wedge between the delivery price and the origin price. This variation distorts the supply and demand of a good from its equilibrium point. Figure 3 in the Appendix provides a graphical representation of this effect.

Section IV: Delivery price results for LNG, wheat and medicine exports

Tables 13, 14 and 15 provide the delivery price calculations for LNG, wheat and medicine exports, respectively. The results are consistent with the unit cost outcomes. The Panama Canal achieves the cheapest delivery price for LNG exports at $7.60/MmBtu. The Suez Canal and Cape of Good Hope prices are $7.81/MmBtu and $7.75/MmBtu, respectively. Furthermore, wheat exports are cheapest using the Cape of Good Hope at $329.12/MT, while the Suez Canal and Panama Canal delivery prices are $336.73/MT and $334.34/MT, respectively. Finally, medicine shipped through the Panama Canal achieves the lowest delivery price, $65.0284/ml. Delivery prices for the Suez Canal and Cape of Good Hope routes are $65.0297/ml and $65.0291/ml.

Using equation (1.3), the transportation costs for each good can be expressed as an ad valorem equivalent rate. From Table 16, it is clear that LNG transportation costs act a huge tariff

---

[25] David Hummels, "Transportation Costs and Adjustment to Trade," *NBER Working Paper*, Purdue University (2012): 3.

on the delivery price of natural gas. The ad valorem rates for each shipping route are 145.25% for the Suez Canal route, 143.29% for the Cape of Good Hope route, and 138.73% for the Panama Canal route.

For wheat exports, Table 17 shows that the ad valorem rate equivalents for transportation costs are noticeably smaller at 26.59%, 23.73% and 25.69% for the Suez Canal, Panama Canal and Cape of Good Hope routes, respectively.

Finally, medicine transportation costs ad valorem equivalent rates are presented in Table 18. The results show very low tariff equivalent rates, which indicates that transportation costs do not represent a large wedge between the origin price and the delivery price for medicine. Still, the rate for the Panama Canal is lowest at 0.044%, while the Suez Canal rate equals 0.045% and the Cape of Good Hope rate equals 0.046%.

Analysis of the delivery price results

From the results above, the Panama Canal route achieves the cheapest delivery price for LNG and medicine exports, but the Cape of Good Hope route produces the lowest delivery price for wheat exports. This outcome contradicts hypothesis (1), which predicts that the Panama Canal will realize the lowest delivery price for all three goods.

Additionally, it is important to note not only which route is the cheapest, but to what extent it differs from the alternate route options. This exposes the competitiveness of each route for each export good.

From Table 19, the nominal delivery price difference for LNG exports is $0.15 between the Panama Canal and the Cape of Good Hope. For wheat exports, Table 20 shows a nominal delivery price difference of $5.21/MT between the Cape of Good Hope and the Panama Canal. In Table 21, the nominal delivery price difference for medicine exports equals $0.0007 between the Panama Canal and the Cape of Good Hope. Based on the data, wheat exports experience the largest nominal variation in delivery prices between the cheapest route and the next best alternative route as compared to LNG exports and medicine.

Moreover, Tables 19, 20 and 21 also provide the percentage difference for the delivery price between transit routes for each U.S. export. Here, the relative difference is very similar for LNG exports and wheat exports. The Panama Canal route is 1.88% cheaper than the Cape of Good Hope route for LNG exports, whereas the percentage difference between the Cape of Good Hope and the Panama Canal for wheat exports is 1.56%. Interestingly, Table 21 shows that the percentage delivery price difference between route options for medicine is essentially 0.00%.

In conclusion, the results from Tables 19, 20 and 21 reveal the competitiveness of each shipping route for each export good. Although the Panama Canal route realizes the lowest delivery price for LNG and medicine, the nominal difference and percentage difference between its price and second best route for each good is less than the results for wheat exports using the Cape of Good Hope. Therefore, the Cape of Good Hope route for wheat is more competitive than the Panama Canal route is for LNG and medicine.

The next section will further examine the Panama Canal expansion against the alternative transit options by developing a sensitivity analysis test to changes in the Panama Canal toll rates. This process will reveal to what extent the Panama Canal represents a competitive transportation route for U.S. exports.

Section V: Sensitivity of transportation costs to changes in the Panama Canal toll rates

Section IV reveals that the delivery prices for the three goods are highly competitive between each shipping route. Therefore, changes to the transportation costs for any of the routes could have a significant impact on shipping practices and global trade flows. For example, maritime trade through the Suez Canal has declined in recent years, in part due to the additional costs incurred to minimize the threat of Somali pirates.[26] The war risk premium shown in Tables 7, 8 and 9 illustrate these costs.

Methodology

As the Panama Canal expansion project progresses, the shipping industry becomes more concerned about the Canal's future toll rates. For example, a report by the Business Monitor International indicates that the Panama Canal Authority (ACP) intends to raise rates on container vessels by 15.45%.[27] However, the report cautions against drastic toll increases because doing so could hurt the Canal's competitiveness and induce shippers to utilize other routes, such as the Suez Canal and the Cape of Good Hope.[28]

With this in mind, this paper will conduct a sensitivity analysis test on the transportation costs using the Panama Canal route under different canal fee circumstances. The test will measure the affect of higher toll rates on the delivery prices for the three goods and compare them to the results using the Suez Canal and the Cape of Good Hope routes.

Specifically, this paper will analyze the transportation costs when toll rates equal 115% (Scenario B) and 130% (Scenario C) of current levels. Scenario B is meant to reflect future toll fees anticipated by the industry, while Scenario C exemplifies an extreme case.

Sensitivity test results

Tables 22, 23 and 24 compare the higher toll rates under Scenarios B and C for each U.S. export good to the Scenario A levels. For example, the total canal fee increases $1.27/MT of wheat between Scenarios A and C. Additionally, Tables 25, 26 and 27 incorporate those higher

---

[26] Alexa K. Sullivan, "Piracy in the Horn of Africa and its effects on the global supply chain", Journal of Transport Security, 2010, Vol. 3 pp: 231-243.

[27] "Panama Freight Transportation Report," *Business Monitor International* (October 1, 2012): accessed through LexisNexis Sept. 23, 2012.

[28] *Ibid.*

toll rates into the unit cost of transportation. As expected the unit costs for LNG and medicine using the Panama Canal route converge with the unit costs using the alternative transit options. Conversely, the unit cost for wheat widens between the Panama Canal and the Cape of Good Hope as a result of high canal fees. The same convergence for LNG and medicine and widening for wheat is observed for delivery prices under Scenarios B and C (Tables 28, 29 and 30).

These results reveal that under Scenarios B and C (115% and 130% current toll rates, respectively) the Panama Canal provides the lowest unit cost of transportation and lowest delivery price for LNG and medicine, but wheat exports realize the lowest unit cost of transportation and lowest delivery price via the Cape of Good Hope route. Therefore, hypothesis (2) does not hold.

Moreover, the sensitivity test illustrates that higher toll fees affect the Panama Canal's competitiveness regarding transportation costs for U.S. exports because higher toll fees create a larger wedge between the origin price and delivery price. This conclusion makes sense based on equations (1.1) - (1.3) explained in Section III

This trend is evident by evaluating the delivery price differences for all three export goods using all three routes under Scenarios B and C. For LNG, Table 34 shows that the delivery price differences under Scenario B and C between the Panama Canal (lowest route) and the Cape of Good Hope (second lowest route) are 1.62% and 1.36%, respectively. Under Scenario A (Table 19), the delivery price difference between the two routes equals 1.88%. For wheat, the delivery price difference widens between the Cape of Good Hope (lowest route) and the Panama Canal (second lowest route) from 1.56% under Scenario A to 1.75% under Scenario B (Table 35). The difference is even greater for Scenario C. Interestingly, Table 36 reveals no change in the delivery price difference for medicine under Scenarios B and C as compared to Scenario A because transportation costs equal such a tiny fraction of the origin price.

Based on the results above, the impact of higher toll fees on delivery prices is not uniform for all three U.S. goods. Specifically, Tables 34, 35 and 36 illustrate that the greatest effect on the competitiveness of using the Panama Canal route is on LNG exports and the smallest effect is on medicine exports. Therefore, the sensitivity analysis test confirms hypothesis (3).

Finally, the results of the sensitivity analysis test suggest that hypothesis (4) holds as well. For any rise in canal toll fees, transportation costs for U.S. LNG exports using the Panama Canal route will be hurt the most. Therefore, this paper expects to observe a greater percentage decrease in the exports of LNG via the Panama Canal to Japan as compared to wheat and medicine if the ACP increases toll rates.

Section VI: Shortcomings of research

This paper presents valuable results on the transportation costs for U.S. exports using competing transit routes. It also exposes the vulnerability of the Panama Canal as a competitive global shipping lane to increased transit fees. However, further research and fine-tuning are necessary to present a complete assessment of the extent to which the Panama Canal expansion will impact U.S. export competitiveness through maritime transportation costs.

First, the transportation costs model can be enhanced. Currently, it makes assumptions about shipping practices. For example, it assumes that all voyages of wheat exports on the Cape of Good Hope route will be transported on a vessel with 200,000 DWT. However, wheat is currently shipped on smaller vessels of approximately 90,000 DWT. Furthermore, vessels of this size are not always available or affordable. To be more accurate with current trends, the model should determine what percent of voyages are shipped on different vessel sizes and apply a weighted average to the transportation calculations. This way, the unit cost of transportation for each route/good option will be as accurate as possible, which will improve the results of the delivery price outcomes.

Additional improvements to the transportation costs model can be added. For example, research has so far been unable to pinpoint an exact insurance rate for bulk shipments of wheat and for 1 TEU of medicines from the U.S. Gulf Coast to Japan. Also, the war risk premium cost included in this paper is generic. In reality, the risk to send a LNG tanker through the Gulf of Aden exceeds the risk for a bulk carrier of wheat because the value of LNG is greater as is the potential harm it can cause. These examples represent more variables that can differentiate the transportation costs between each route and good, further adding to the depth of analysis.

An extension of this paper could be completed to correct for these shortcoming. In doing so, it will present more convincing results, which can more confidently conclude to what extent the Panama Canal expansion impacts transportation costs and competitiveness for U.S. exports.

Section VII: Conclusions

This paper makes an important first step towards evaluating to what extent the Panama Canal expansion will alter transportation costs for U.S. exports, and by extension whether it will make U.S. exports more competitive in the global market.

Research results

As evident from the results in Section IV, LNG exports are expected to gain the most from the new channel. This route generates the lowest unit cost of transportation and the lowest delivery price, which U.S. LNG exporters can utilize to improve their position in the Japanese LNG market. However, the sensitivity analysis test in Section V reveals that LNG exports also have the most to lose if the Panama Canal Authority raises toll fees. Therefore, this paper exposes the uncertainty of the long-term benefit of the Panama Canal expansion to future LNG exports from the U.S.

This research also evinces that wheat exports are most competitive using the Cape of Good Hope route because this route harnesses the benefits of economies of scale from a larger vessel. The same probably applies to other U.S. commodities like soy and corn, which are shipped in similarly sized break bulk carriers.

The paper also shows that transportation costs are not influential for medicines because they constitute a tiny fraction on the final delivery price. Other high value-added products like medical devices and semiconductors would likely exhibit similar results.

Therefore, the impact of the Panama Canal expansion on the overall competitiveness of U.S. exports is inconclusive. It appears to benefit those export goods with very expensive transportation costs, such as LNG because it offers the fastest transportation time. However, it is not able to maximize economies of scale from larger vessels that benefit relatively cheap products like wheat, nor does it distinguish itself from other shipping routes for high value-added goods that are not as sensitive to transportation costs.

Appropriate decision making takeaways

The results from this paper can inform many parties on appropriate decision making. First, it highlights that uncertainty surrounds whether the expansion of the Panama Canal will improve U.S. export competitiveness significantly. This conclusion contradicts many daily headlines and common perception. Hopefully, it will deepen the discussion currently underway.

Second, this research can enlighten U.S. exporters regarding how to achieve lower transportation costs, which will improve access to markets and maximize profits. For example, it signals to U.S. wheat exporters that utilizing larger vessels is more valuable than transit times to generate the lowest delivery price. Similarly, potential LNG exporters can exploit their competitiveness in the Japan LNG market by using the Panama Canal route. Conversely, exporters of high value-added goods like medicine should focus more on the quality of shipping, rather than the cost.

Third, U.S. businesses can appropriately direct future investments. For example, liquefaction plants and related infrastructure decisions could be directed to the U.S. Gulf Coast where LNG exports can concentrate. The centralization of resources would further cut costs, thus creating a virtuous circle for U.S. LNG export competitiveness. Additionally, U.S. natural gas producers could decide to increase production levels to accommodate LNG exports, as well as supply the domestic market.

Similarly, many ports authorities along the U.S. east coast are investing billions of dollars in infrastructure upgrades and deeper channels to accommodate greater volumes of trade. This paper identifies instances when these expenditures are wise decisions and when they should be avoided. Specifically, this paper finds that U.S. ports that anticipate future LNG or similar transportation expensive exports to Asia are well advised to make port investments to benefit from the Panama Canal expansion. However ports that will export predominately bulk and container cargoes should reconsider whether it is prudent to spend on upgrades.

Fifth, public policy decision makers can implement wise legislation. Specifically, the ACP can learn from this research how best to set canal transit fees such that the Panama Canal improves its competitiveness in transportation costs vis-à-vis alternative shipping routes. For example, the transportation costs model reveals that toll rates should be lowered for bulk carriers to contend with the Cape of Good Hope route, whereas the sensitivity analysis test concludes that transit fees should not be increased significantly for LNG tankers. This knowledge can help the ACP maximize the value of the canal expansion in order to provide greater benefits to the Panamanian people as a whole.

In conclusion, this paper tries to estimate the effect of the Panama Canal expansion on the competitiveness of U.S. exports through transportation costs. The goal is to inform policymakers, businesses, the shipping industry and society such that they can determine the proper policies and make wise investments. Hopefully, the result is that the United States trades more efficiently in order to maximize the welfare gains from trade.

References

Armbruster, Bill "Game Changer: Expansion of the Panama Canal Will Reshape Global Trade Patterns." Cargo Business News. http://www.cargobusinessnews.com/Feb10/portcomm_game_changer.html(accessed April 18, 2013).

"Canal History." Suez Canal Authority. http://www.suezcanal.gov.eg/sc.aspx?show=8 (accessed November 3, 2012).

"Country Analysis Briefs: Japan." U.S. Energy Information Administration, June 4, 2012. http://www.eia.gov/countries/cab.cfm?fips=JA (accessed October 10, 2012).

"Dimensions for Future Lock Chambers and 'New Panamax' Vessels." Panama Canal Authority. Op's Advisory to Shipping No. A-02-2009. http://www.pancanal.com/common/maritime/advisories/2009/a-02-2009.pdf (accessed October 10, 2012).

"End of Construction." Panama Canal Authority. http://www.pancanal.com/eng/history/history/end.html (accessed October 10, 2012).

"Fearnley: Lng Rates to Drop." LNG World News. http://www.lngworldnews.com/fearnley-lng-rates-to-drop/ (accessed March 5, 2013).

Gostelow, Max. "Consultant Expects More Than $1 Million in Panama Canal Lng Fees," *Platts LNG Daily*, September 12, 2012. http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Shipping/8716172 (accessed March 5, 2013).

Hansen, Brian and Benno Spencer. "Panama Canal Expansion Seen Boosting Prospect for Gulf Coast LNG Exports to Asia," *Platts Inside FERC* (August 6, 2012): accessed through LexisNexis Sept. 20, 2012.

Hummels, David. "Transportation Costs and Adjustment to Trade." *NBER Working Paper*, Purdue University (2012).

"Infosheet No.30: Modern ship size definitions," *Lloyd's Register*, July 11, 2012. http://www.lr.org/Images/30%20ship%20sizes_tcm155-173543.pdf (accessed October 16, 2012).

Institute for Chartered Shipbrokers. "The Reasons for Sea Transport." In *Introduction to Shipping*. 2005. 2nd ed. Livingston, U.K.: Witherby Seamanship International, 2008.

Institute for Chartered Shipbrokers. "Shipping and International Trade." In *Economics of Sea Transport and International Trade*. 2005. 2nd ed. Livingston, U.K.: Witherby Seamanship International, 2008.

Johnson, Tim. "Widening of Panama Canal Will Remake World Trade Patterns," *McClatchy Newspapers*, August 6, 2012. http://www.mcclatchydc.com/2012/08/06/159848/widening-of-panama-canal-will.html (accessed October 10, 2012).

"LNG insurance rates jump on lawless waters, piracy," *Reuters*, September 7, 2011. http://www.arabianbusiness.com/lng-insurance-rates-jump-on-lawless-waters-piracy-419273.html (accessed October 10, 2012).

"Panama Canal and the Port of New Orleans Renew Strategic Alliance." Panama Canal Authority. Press Release, Aug. 8, 2011, http://www.pancanal.com/eng/pr/press-releases/2011/08/08/pr420.html (accessed October 10, 2012).

"Panama Canal Charge," Hapag-Lloyd Press Release, Dec. 6, 2010. http://www.hapag-lloyd.com/en/press_and_media/press_releases.html. (accessed March 6, 2013).

"Panama Canal Sets New Tonnage Record." Panama Canal Authority. Press Release, October 10, 2012. http://www.pancanal.com/eng/pr/press-releases/2012/10/10/pr454.html (accessed October 10, 2012).

"Panama Freight Transportation Report," *Business Monitor International* (October 1, 2012): accessed through LexisNexis Sept. 23, 2012.

"Q-max." Maritime-Connector. http://www.maritime-connector.com/wiki/q-max (accessed March 6, 2013).

Rodrigue, Dr. Jean-Paul. "Transportation, Globalization and International Trade." The Geography of Transport Systems.http://people.hofstra.edu/geotrans/index.html (accessed February 13, 2013).

"Short-Term Energy Outlook." U.S. Energy Information Administration. November 6, 2012. http://www.eia.gov/forecasts/steo/pdf/steo_full.pdf (accessed November 10, 2012)

Stigset, Marianne, and Gelu Sulugiuc. "Suez Canal, Carrying 8% of Trade, Open Amid Unrest." *Bloomberg*. http://www.bloomberg.com/news/2011-01-31/egypt-s-suez-canal-carrying-8-of-world-trade-remains-open-amid-violence.html (accessed November 3, 2012).

"Suez Canal Surcharge & Piracy Risk Surcharge." MSC Press Release, Dec. 4, 2012. http://wwwmscbelgium.com/news. (accessed March 6, 2013).

Sullivan, Alexa K. "Piracy in the Horn of Africa and its effects on the global supply chain", Journal of Transport Security, 2010, Vol. 3 pp: 231-243.

Notteboom, Dr. Theo, and Dr. Jean-Paul Rodrigue. "Challenges to and Challengers of the Suez Canal." *Port Technology International*, 2008. http://www.porttechnology.org/ (accessed March 5, 2013).

UN Comtrade. http://www.comtrade.un.org/

"Update 1-Diana Shipping Charters Vessel at 76 Pct Lower Rate," *Reuters*, July 5, 2012. http://www.reuters.com/article/2012/07/05/dianashipping-charter-idUSL3E8I53O420120705 (accessed October 10, 2012).

U.S. Dept. of Agriculture, Agricultural Marketing Service. *Grain Transportation Report*. January 31, 2013. http://dx.doi.org/10.9752/TS056.01-13-2013 (accessed February 2, 2013).

Wiese Bockmann, Michelle. "Reshaping Panama Canal Trade Means Boom in U.s. Gas to Asia," *Bloomberg*, February 1, 2013. http://www.bloomberg.com/news/2013-02-01/reshaping-panama-canal-trade-means-boom-in-u-s-gas-flow-to-asia.html (accessed February 2, 2013).

"Will Low Priced Eco-Ships Delay the Market Recovery?" gCaptain. http://www.gcaptain.com/bulk-carrier-update-market-tough/ (accessed April 18, 2013).

The World Merchant Fleet in 2011. Equasis, 2011. http://equasis.org (accessed March 2, 2013).

"World's Largest Container Ship Over Time." Container Transportation.http://www.container-transportation.com/worlds-largest-container-ship.html (accessed February 6, 2013).

Appendix

Figure 1: Three main shipping routes from the U.S. Gulf Coast to Japan

a. Origin point is the U.S. Gulf Coast for all three routes

b. Suez Canal and Cape of Good Hope routes around Africa continent

c. Final destination is Tokyo, Japan for all three routes

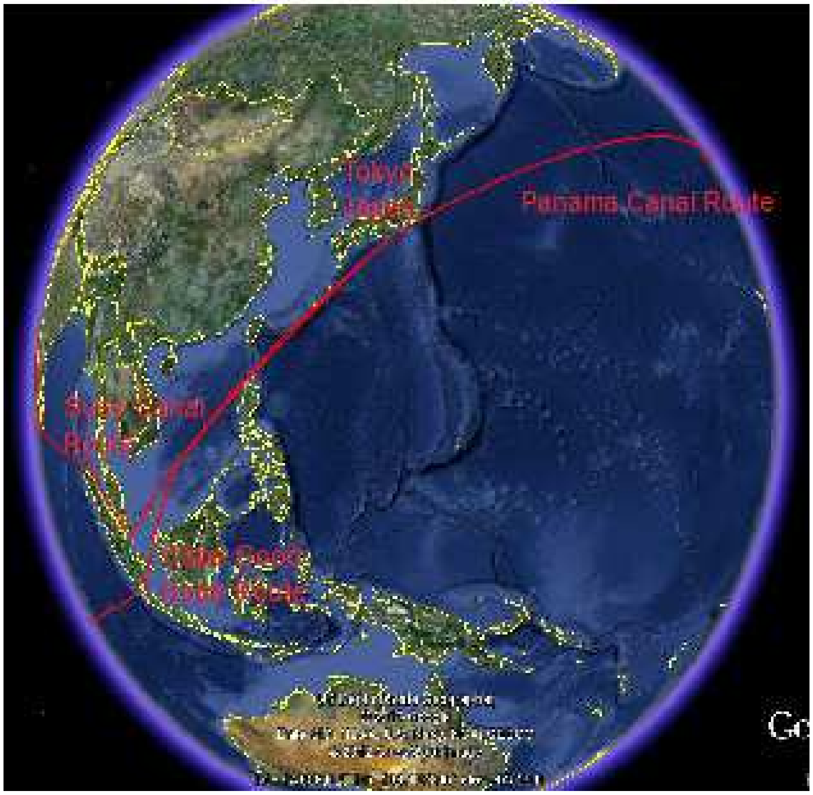


Figure 2: Modern vessel size and classifications, according to Lloyd's Register[29]

Modern ship size definitions

ULCC: Ultra Large Crude Carriers 300,000 - 550,000 tonnes deadweight. Used for carrying crude oil on long haul routes from the Arabian Gulf to Europe, America and the Far East, via the Cape of Good Hope normally discharging at custom built terminals.

VLCC: Very Large Crude Carriers 200,000 - 299,999 tonnes deadweight. On similar routes to ULCCs but with greater flexibility in discharging port options owing to their smaller size, and for this reason also employed ex Mediterranean, West African and even North Sea Terminals. They can be ballasted through the Suez Canal.

AFRAMAX: A tanker of maximum 79,999 tonnes deadweight, or the largest tanker size in the Average Freight Rate Assessment Scale.

MALACCAMAX: The maximum hull form using the maximum draught permissible to pass through the Strait of Malacca in Malaysia, which is 25 metres deep.

HANDYSIZE BULKERS: Up to 50,000 tonnes deadweight. This allows the ships to enter smaller ports around the world and to pick up smaller cargoes.

MINIBULKERS:
Less than 10,000 tonnes deadweight. Mainly employed in the coastal and short sea trade.

PANAMAX: The largest acceptable size in order to transit the Panama Canal. Ships' lengths are restricted to 275m, and maximum permitted width is slightly more than 32m. Average deadweight of such a ship is about 65,000 to 80,000 tonnes, cargo intake usually restricted to approximately 52,500 tonnes on the Panama Canal draft.

SUEZMAX: Before its closure in 1967 the Suez Canal could only cope with 80,000 tonne deadweight tankers and the maximum draft available was 37 feet. When the Suez Canal reopened in 1975 the maximum tonnage was increased to 200,000 tonnes deadweight and maximum draft to 66 feet.

CAPESIZE: 100 – 180,000 tonnes deadweight, draft approx. 17m. To govern the design of large ships built to serve deepwater terminals handling raw materials, such as iron ore, from Brazil. Too big for the Panama or Suez canals, Capesize vessels voyage via Cape Horn or the Cape of Good Hope.

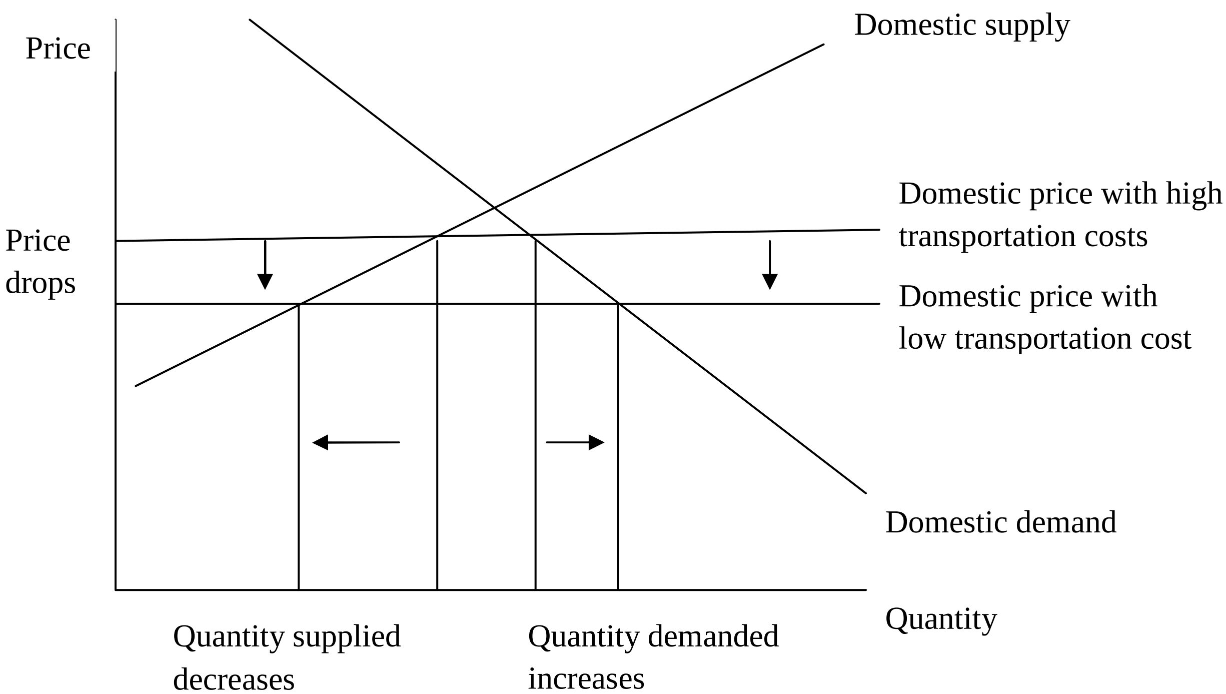
HANDYMAX BULKERS:
35 -50,000 tonnes deadweight. This allows for each category to increase in size and some now consider the larger size in this Range as the Handymax.

Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as 'Lloyd's Register'. Lloyd's Register assumes no responsibility and shall not be liable

Revised: July 11 2012

[29] "Infosheet No.30: Modern ship size definitions," *Lloyd's Register*, July 11, 2012. http://www.lr.org/Images/30%20ship%20sizes_tcm155-173543.pdf (accessed October 16, 2012)

Figure 3: The effect of lower transportation costs on domestic prices and domestic levels of supply and demand[30]



[30] Graph is adapted from *Economics of Sea Transport and International Trade* p.213.

Table 1: Transit time for LNG exports from the U.S. Gulf Coast to Tokyo, Japan

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Distance (nautical miles)[31]	14,520.00	15,520.00	9,133.50
Ave speed (knots)[32]	18.00	18.00	18.00
Est. Canal transit (days)[33]	0.67	-	1.07
Transit time (days)	34.28	35.93	22.21

Table 2: Transit time for wheat exports from the U.S. Gulf Coast to Tokyo, Japan

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Distance (nautical miles)[34]	14,520.00	15,520.00	9,133.50
Ave speed (knots)[35]	16.00	16.00	16.00
Est. Canal transit (days)[36]	0.67	-	1.07
Transit time (days)	38.48	35.93	24.85

Table 3: Transit time for medicine exports from the U.S. Gulf Coast to Tokyo, Japan

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Distance (nautical miles)[37]	14,520.00	15,520.00	9,133.50
Ave speed (knots)[38]	25.00	25.00	25.00
Est. Canal transit (days)[39]	0.67	-	1.07
Transit time (days)	24.87	25.87	16.29

[31] Distances are determined using Google Earth's geo-spatial tools. Refer to Figure 1.
[32] Brian Hansen and Benno Spencer, "Panama Canal Expansion Seen Boosting Prospect for Gulf Coast LNG Exports to Asia," *Platts Inside FERC* (August 6, 2012), accessed through LexisNexis Sept. 20, 2012.
[33] Panama Canal transit time obtained from ACP press release: "Panama Canal Sets New Tonnage Record." Panama Canal Authority. October 10, 2012. http://www.pancanal.com/eng/pr/press-releases/2012/10/10/pr454.html; Suez Canal average transit time obtained from Suez Canal Authority website, http://www.suezcanal.gov.eg/sc.aspx?show=13#.
[34] Distances are determined using Google Earth's geo-spatial tools. Refer to Figure 1.
[35] *Introduction to Shipping*, p.12
[36] "Panama Canal Sets New Tonnage Record"; Suez Canal Authority website.
[37] Refer to Figure 1.
[38] *Introduction to Shipping*, p.12
[39] "Panama Canal Sets New Tonnage Record"; Suez Canal Authority website.

Table 4: Vessel sizes and cargo capacities for LNG exports

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Dead Weight Tons (DWT)[40]	130,340.00	130,340.00	118,000.00
Capacity (CM)[41]	266,000.00	266,000.00	200,000.00
Boil-off Gas (BOG)[42]	6%	6%	6%
Heel[43]	5%	5%	5%
MCF Nat Gas/1 CM LNG	24.00	24.00	24.00
MCF Nat Gas/vessel	5,681,760.00	5,681,760.00	4,272,000.00
MmBtu/1 MCF Nat Gas	1.023	1.023	1.023
MmBtu Nat Gas/vessel	5,812,440.48	5,812,440.48	4,370,256.00

Table 5: Vessel sizes and cargo capacities for wheat exports

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Dead Weight Tons (DWT)[44]	150,000.00	200,000.00	120,000.00
Cargo Capacity (MT)	116,666.67	155,555.56	93,333.33

Table 6: Vessel sizes and cargo capacities for medicine

	Suez Canal	*Cape Good Hope*	*Panama Canal*
TEUs[45]	13,000.00	16,000.00	12,500.00
Vials/TEU[46]	38,880.00	38,880.00	38,880.00
ML/TEU[47]	777,600.00	777,600.00	777,600.00

[40] DWT for LNG tankers are estimates based on similar sized LNG tankers.
[41] LNG vessel capacities are determined based on each route's limitations. The Cape of Good Hope and Suez Canal can accommodate the largest LNG tanker, which is a Q-Max tanker with 266,000 CM. The Panama Canal expansion can accommodate LNG tankers with 200,000 CM based on lock dimensions.
[42] M.M. Faruque Hasan, Alfred Minghan Zheng, and I.A. Karimi, *Minimizing Boil-Off Losses in Liquefied Natural Gas Transportation* (National University of Singapore, 2009),http://xa.yimg.com/kq/groups/3004572/389344521/name/Minimizing%20Boil-Off%20Losses(accessed February 7, 2013).
[43] *Ibid.*
[44] Wheat vessel capacities are determined with the same process as LNG tankers. Typical bulk carriers range in size from 120,000 DWT to 200,000 DWT, although there are some ore carriers which reach 400,000 DWT. Furthermore, ACP reports indicate that the new canal will likely encourage the use of bulk carriers of 120,000 DWT. Therefore, the Panama Canal route will use a vessel with 120,000 DWT, Suez Canal 150,000 DWT, and the Cape of Good Hope will use the largest typical bulk carrier with 200,000 DWT.
[45] Container vessel TEU amounts were determined for each shipping route based on canal authority website information for the Suez Canal and Panama Canal routes and data on the largest container vessels in service for the Cape of Good Hope route.
[46] Determination of the number of vials/TEU of Remodulin was based on the following calculations: 36 vials/ box (box size is 12"L x 12"W x 4"H); 108 boxes/pallet (pallet size is 36"L x 36"W x 48"H, comprised of 12 rows with 9 boxes per row).
[47] One vial of Remodulin holds 20 mL. Therefore, 38,880 vials/TEU x 20mL/vial = 777,600 mL/TEU.

Table 7: Transportation costs for LNG exports, round trip (Scenario A)

LNG Tanker Charter	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Fee/day[48]	$125,000.00	$125,000.00	$125,000.00
Total cost	$8,569,444.44	$8,981,481.48	$5,552,881.94
Cost/MmBtu Nat Gas	$1.47	$1.55	$1.27
Canal Transit[49]	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Canal Fee (full laden)	$316,038.24	$0.00	$316,038.24
Canal Fee (ballast)	$264,088.66	$0.00	$264,088.66
Cost/MmBtu	$0.0998	$0.0000	$0.1327
LNG Insurance	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Cost/day[50]	$1,572.00	$1,572.00	$1,572.00
War risk premium & costs[51]	$100,000.00	$0.00	$0.00
Total Cost	$307,769.33	$112,951.11	$69,833.04
Cost/MmBtu	$0.0530	$0.0194	$0.0160

Table 8: Transportation costs for wheat exports, round trip (Scenario A)

Bulk Carrier Charter Fee	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Fee/day[52]	$14,000.00	$14,000.00	$14,000.00
Total cost	$1,077,416.67	$1,005,925.93	$695,921.04
Cost/MT	$9.24	$6.47	$7.46
Canal Transit[53]	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Canal Fee (fully laden)	$308,598.44	$0.00	$218,823.53
Canal Fee (ballast)	$255,239.31	$0.00	$175,254.64
Cost/MT	$4.83	$0.00	$4.22
Cargo Insurance	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Cost/day[54]	Not available	Not available	Not available

[48] "Fearnley: LNG Rates to Drop," *LNG World News*, http://www.lngworldnews.com/fearnley-lng-rates-to-drop/ (accessed March 5, 2013).

[49] The canal transit fees for LNG tankers are based on proprietary information provided by PFC Energy. Canal fees for the new Panama Canal have not been released yet. So PFC Energy based its calculations on a Suez Canal generic transit charge, which it calculated to be $250,000 for these LNG tankers.

[50] "LNG insurance rates jump on lawless waters, piracy," *Reuters*, September 7, 2011. http://www.arabianbusiness.com/lng-insurance-rates-jump-on-lawless-waters-piracy-419273.html (accessed October 10, 2012).

[51] Dr. Theo Notteboom and Dr. Jean-Paul Rodrigue, "Challenges to and Challengers of the Suez Canal," *Port Technology International*, 2008, page 3, http://www.porttechnology.org/ (accessed March 5, 2013).

[52] "Will Low Priced Eco-Ships Delay the Market Recovery?" *gCaptain*, http://www.gcaptain.com/bulk-carrier-update-market-tough/ (accessed March 5, 2013).

[53] The Suez Canal transit fee is determined by using the Toll Calculator feature on the Suez Canal Authority website. It can be found here: http://www.suezcanal.gov.eg/calc.aspx. The Panama Canal transit fee is determined from the ACP's published tariff rates, which can be found here: http://www.pancanal.com/eng/op/tolls.html

War risk premium & costs[55]	$100,000.00	$0.00	$0.00
Total cost	$200,000.00	$0.00	$0.00
Cost/MT	$1.71	$0.00	$0.00

Import Tariff[56]	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Average MFN Rate	21.3%	21.3%	21.3%
Cost/MT	$56.66	$56.66	$56.66

Table 9: Transportation cost for medicine, one way (Scenario A)

Transportation Costs (per TEU)	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Ocean Freight Rate[57]	$2,987.97	$2,594.92	$1,954.70
Canal fee[58]	$30.57	$ -	$74.00
Canal surcharge[59]	$25.00	$ -	$20.00
War risk[60]	$55.00	$ -	$ -
Cost/TEU	$3,098.54	$2,594.92	$2,048.70

Cargo Insurance (per TEU)	*Suez Canal*	*Cape Good Hope*	*Panama Canal*
Total cost[61]	$20,000.00	$20,000.00	$20,000.00

[54] This paper was unable to find a reliable cargo insurance rate for bulk wheat exports from the U.S. to Japan.
[55] Notteboom et al.
[56] Japan's tariff rates for wheat are retrieved from the World Trade Organization (WTO) Tariff Database at http://tariffdata.wto.org/ReportersAndProducts.aspx.
[57] The estimated OFR costs are based on instant quote from www.globalforwarding.com, which includes all costs (bunkers, THC, CAF).
[58] Suez Canal toll calculator on website; from ACP website, showing current toll fees.
[59] "Suez Canal Surcharge & Piracy Risk Surcharge," MSC Press Release, Dec. 4, 2012. http://wwwmscbelgium.com/news. (accessed March 6, 2013).; "Panama Canal Charge," Hapag-Lloyd Press Release, Dec. 6, 2010. http://www.hapag-lloyd.com/en/press_and_media/press_releases.html. (accessed March 6, 2013).
[60] "Suez Canal Surcharge & Piracy Risk Surcharge"
[61] This paper was unable to find a reliable cargo insurance rate for 1 TEU of medicines worth $50 million from the U.S. Gulf Coast to Japan. $20,000/TEU is an estimation.

Table 10: Unit cost of transportation for LNG exports, round trip (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Liquefaction charge[62]	$3.00	$3.00	$3.00
Charter Fee	$1.47	$1.55	$1.27
Canal Fees	$0.0998	$0.0000	$0.1327
Insurance	$0.0530	$0.0194	$0.0160
Tariff[63]	$0.00	$0.00	$0.00
Unit Cost ($/MmBtu)	$4.63	$4.56	$4.42

Table 11: Unit cost of transportation for wheat exports, round trip (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Charter Fee	$9.24	$6.47	$7.46
Canal fee	$4.83	$0.00	$4.22
Insurance	Not available	Not available	Not available
Tariff	$56.66	$56.66	$56.66
Unit Cost ($/MT)	$70.73	$63.12	$68.34

Table 12: Unit cost of transportation for medicine, one way (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Trans cost/TEU	$2,538.29	$2,594.92	$1,621.11
Insurance	$20,000.00	$20,000.00	$20,000.00
Tariff[64]	$0.00	$0.00	$0.00
Unit Cost ($/TEU)	$23,098.54	$22,594.92	$22,048.70
Unit Cost ($/ml)	$0.0297	$0.0291	$0.0284

[62] The liquefaction charge comes from proprietary research completed by PFC Energy.
[63] Japan's tariff rates for LNG are retrieved from the World Trade Organization (WTO) Tariff Database at http://tariffdata.wto.org/ReportersAndProducts.aspx.
[64] Japan's tariff rates for medicines (pharmaceuticals) are retrieved from the World Trade Organization (WTO) Tariff Database at http://tariffdata.wto.org/ReportersAndProducts.aspx.

Table 13: Delivery price for LNG exports, in MmBtu (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Origin Price[65]	$2.77	$2.77	$2.77
Mark-up price (115%)[66]	$3.19	$3.19	$3.19
Unit Cost Trans	$4.63	$4.56	$4.42
Delivery Price ($/MmBtu)	$7.81	$7.75	$7.60

Table 14: Delivery price for wheat exports, in metric tonnes (MT) (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Origin Price	$266.00	$266.00	$266.00
Unit Cost Trans	$70.73	$63.12	$68.34
Delivery Price ($/MT)	$336.73	$329.12	$334.34

Table 15: Delivery price for medicine, in milliliters (ml) (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Origin Price[67]	$65.00	$65.00	$65.00
Unit Trans Cost	$0.0297	$0.0291	$0.0284
Delivery Price ($/ml)	$65.0297	$65.0291	$65.0284

[65] The U.S. Energy Information Administration estimates that the average Henry Hub price for natural gas will be $2.77/MmBtu in 2012. The report is: "Short-Term Energy Outlook." U.S. Energy Information Administration. November 6, 2012. http://www.eia.gov/forecasts/steo/pdf/steo_full.pdf (accessed November 10, 2012). Henry Hub, Louisiana is the major hub for the U.S. natural gas pipeline distribution system. Natural gas prices are based on the price received at this location.

[66] The mark up rate of 115% derives from proprietary research conducted by PFC Energy. This amount was found in other resources as well.

[67] In the U.S., the average recommended wholesale price for Remodulin is $65 per milliliter. For more information, see: http://www.sec.gov/Archives/edgar/data/1082554/000095013302002150/w61118exv99.htm.

Table 16: Ad valorem tariff equivalent of LNG export transportation costs (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Delivery price	$7.81	$7.75	$7.60
Origin price	$3.19	$3.19	$3.19
Ad valorem rate	145.25%	143.29%	138.73%

Table 17: Ad valorem tariff equivalent of wheat export transportation costs (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Delivery price	$336.73	$329.12	$334.34
Origin price	$266.00	$266.00	$266.00
Ad valorem rate	26.59%	23.73%	25.69%

Table 18: Ad valorem tariff equivalent of medicine export transportation costs (Scenario A)

	Suez Canal	*Cape Good Hope*	*Panama Canal*
Delivery price	$65.0297	$65.0291	$65.0284
Origin price	$65.00	$65.00	$65.00
Ad valorem rate	0.046%	0.045%	0.044%

Table 19: Delivery price differences for LNG exports (Scenario A)

	Delivery Price	Nominal value change	Percent value change
Suez Canal	$7.81		
Cape Good Hope	$7.75	$0.06	0.80%
Panama Canal	$7.60	$0.15	1.88%

Table 20: Delivery price differences for wheat exports (Scenario A)

	Delivery Price	Nominal value change	Percent value change
Suez Canal	$336.73		
Panama Canal	$334.34	$2.39	0.71%
Cape Good Hope	$329.12	$5.21	1.56%

Table 21: Delivery price differences for medicine (Scenario A)

	Delivery Price	Nominal value change	Percent value change
Suez Canal	$65.0297		
Cape of Good Hope	$65.0291	$0.0006	0.0010%
Panama Canal	$65.0284	$0.0007	0.0011%

Table 22: Canal toll fees for LNG exports, round trip (Scenarios A, B and C)

	Scenario A	*Scenario B*	*Scenario C*
Canal fee scenario	100%	115%	130%
Canal fee (fully laden)	$316,038.24	$363,443.98	$410,849.71
Canal fee (ballast)	$264,088.66	$303,701.96	$343,315.26
Total canal fee	$580,126.90	$667,145.94	$754,164.97
Total canal fee/MmBtu	$0.1327	$0.1527	$0.1726

Table 23: Canal toll fees for wheat exports, round trip (Scenarios A, B and C)

	Scenario A	*Scenario B*	*Scenario C*
Canal fee scenario	100%	115%	130%
Canal fee (fully laden)	$218,823.53	$251,647.06	$284,470.59
Canal fee (ballast)	$175,254.64	$201,542.83	$227,831.03
Total canal fee	$394,078.17	$453,189.89	$512,301.62
Total canal fee/MT	$4.22	$4.86	$5.49

Table 24: Canal toll fees for medicine exports, one way (Scenarios A, B and C)

	Scenario A	*Scenario B*	*Scenario C*
Canal fee scenario	100%	115%	130%
Canal fee (fully laden)	$74.00	$85.10	$96.20
Canal fee (ballast)	N/A	N/A	N/A
Total canal fee	$74.00	$85.10	$96.20
Total canal fee/mL	$0.000095	$0.000109	$0.000124

Table 25: Unit cost of transportation for LNG, round trip (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Liquefaction charge	$3.00	$3.00	$3.00	$3.00
Charter Fee	$1.47	$1.55	$1.27	$1.27
Canal Fees	$0.0998	$0.0000	$0.1527	$0.1726
Insurance	$0.0530	$0.0194	$0.0160	$0.0160
Tariff	$0.00	$0.00	$0.00	$0.00
Unit Cost ($/MmBtu)	$4.63	$4.56	$4.44	$4.46

Table 26: Unit cost of transportation for wheat, round trip (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Charter Fee	$9.24	$6.47	$7.46	$7.46
Canal fee	$4.83	$0.00	$4.86	$5.49
Insurance	Not available	Not available	Not available	Not available
Tariff	$56.66	$56.66	$56.66	$56.66
Unit Cost ($/MT)	$70.73	$63.12	$68.97	$69.60

Table 27: Unit cost of transportation for medicine, one way (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Trans cost	$3,098.54	$2,594.92	$2,059.80	$2,070.90
Insurance	$20,000.00	$20,000.00	$20,000.00	$20,000.00
Tariff	$0.00	$0.00	$0.00	$0.00
Cost ($/TEU)	$23,098.54	$22,594.92	$22,059.80	$22,070.90
Unit Cost ($/ml)	$0.0297	$0.0291	$0.0284	$0.0284

Table 28: Delivery price for LNG exports, in MmBtu (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Origin Price	$2.77	$2.77	$2.77	$2.77
Mark-up price (115%)	$3.19	$3.19	$3.19	$3.19
Unit Cost Trans	$4.63	$4.56	$4.44	$4.46
Delivery Price ($/MmBtu)	$7.81	$7.75	$7.62	$7.64

Table 29: Delivery price for wheat exports, in metric tonnes (MT) (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Origin Price	$266.00	$266.00	$266.00	$266.00
Unit Cost	$70.73	$63.12	$68.97	$69.60
Delivery Price ($/MT)	$336.73	$329.12	$334.97	$335.60

Table 30: Delivery price for medicine exports, in milliliters (ml) (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Origin Price	$65.00	$65.00	$65.00	$65.00
Unit Trans Cost	$0.0297	$0.0291	$0.0284	$0.0284
Delivery Price	$65.0297	$65.0291	$65.0284	$65.0284

Table 31: Ad valorem tariff equivalent of LNG export transportation costs (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Delivery price	$7.81	$7.75	$7.62	$7.64
Origin price	$3.19	$3.19	$3.19	$3.19
Ad valorem rate	145.25%	143.29%	139.36%	139.98%

Table 32: Ad valorem tariff equivalent of wheat export transportation costs (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Delivery price	$336.73	$329.12	$334.97	$335.60
Origin price	$266.00	$266.00	$266.00	$266.00
Ad valorem rate	26.59%	23.73%	25.93%	26.17%

Table 33: Ad valorem tariff equivalent of medicine export transportation costs (Scenarios B and C)

	Suez Canal	*Cape Good Hope*	*Scenario B*	*Scenario C*
Delivery price	$65.0297	$65.0291	$65.0284	$65.0284
Origin price	$65.00	$65.00	$65.00	$65.00
Ad valorem rate	0.046%	0.045%	0.044%	0.044%

Table 34: Delivery price differences for LNG exports (Scenarios B and C)

	Delivery Price	Nominal value change	Percent value change
Suez Canal	$7.81		
Cape Good Hope	$7.75	$0.06	0.80%
Panama Canal, Scenario C	$7.64	$0.11	1.36%
Panama Canal, Scenario B	$7.62	$0.13	1.62%

Table 35: Delivery price differences for wheat exports (Scenarios B and C)

	Delivery Price	Diff. from next best	Percent change
Suez Canal	$336.73		
Panama Canal, Scenario C	$335.60	$1.12	0.33%
Panama Canal, Scenario B	$334.97	$1.76	0.52%
Cape of Good Hope	$329.12	$5.85	1.75%

Table 36: Delivery price differences for medicine exports (Scenarios B and C)

	Delivery Price	Diff. from next best	Percent change
Suez Canal	$65.0297		
Cape Good Hope	$65.0291	$0.0006	0.0010%
Panama Canal, Scenario C	$65.0284	$0.0007	0.0010%
Panama Canal, Scenario B	$65.0284	$0.0007	0.0011%