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The Economic Impact of open Arctic Routes on Global Maritime LNG Trade

by

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Richard van den Broek
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Abstract

As the Arctic ice level retreat due to global warming, (trans)arctic sailing routes become economically more viable. Several recent estimates predict the fist ice-free summers in 2030-2040. Shipping on the Northern Sea Route can reduce sailing distance by 40% for European-Asian trade and even more when shipping directly across the North Pole becomes feasible.

The Arctic routes are particularly interesting for LNG shipping due to the high sensitivity of this form of transport to time. While many studies have investigated the economic viability of the Arctic routes, research on the economic impacts is barely undertaken. This thesis investigates the economic impact of increasing navigability of Arctic shipping routes on global maritime LNG trade. Through the Global Simulation Model (GSIM), the effects on trade values, directions, prices, route use and welfare effects have been analysed.

This research uses four feasible scenarios. These four navigability scenarios are combined with two main scenarios, climatological and aggregated, giving a total of eight analyses. The main scenarios are used to evaluate the impact of supply and demand locations on the impact of more open Arctic shipping routes. The climatological scenario takes only into account current import and production capacity, thereby isolating the effect of higher navigability. The aggregated scenario takes into account expected new locations and capacity of supply and demand among which are a strong increase in Australian production, production in the Kara region (Russian Arctic) and the shift of the US from importer to exporter of gas.

We find that locations of supply and demand are of critical impact on the use of the Arctic routes. At current locations, i.e. the climatological scenario, only Norway as exporter and Japan, China/Taiwan and South Korea as importers slightly benefit in terms of welfare. Only for Norway, due to its small market share, this is a significant effect while impacts on other actors and global trade in general is negligible. Taking into account future projects, a larger role of the Arctic routes can be expected. The NWP, with a total traded value of $1.64 billion (0.47% of global LNG trade), will only be used for Northeast America to Asia trades. The NSR will be used more extensively for multiple importers and exporters (approx. $4.36b and 1.32% of total traded value). Regions that directly benefit are Norway, Russia Kara region and Northeast America as exporters and Japan, China/Taiwan and South Korea as importers. This at the expense of surplus for exporting regions Australia, Arabian Peninsula and the Malay Archipelago, which are exposed to more competition. European markets have to cope with higher consumer prices because a part of supply moves to Asia. Interestingly, some non-Arctic exporters, of which Algeria significantly, enjoy higher producer prices and surpluses as a result.

Overall a very small (-0.04%) decrease in total traded value is observed. It is counterintuitive that when trade becomes less restricted, traded value decreases but it is explained by a stronger net effect on prices than on quantities. This is supported by the fact that the net producer surplus effect is negative. The opening of the Arctic routes has a slightly negative impact on Suez and Panama Canal transits.

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List of Abbreviations

A-HN	Aggregated, High Navigability Scenario
A-LN	Aggregated, Low Navigability Scenario
A-ML	Aggregated, Most Likely Navigability Scenario
A-NI	Aggregated, No Ice Navigability Scenario
AR	Arctic Route
C-HN	Climatological, High Navigability Scenario
C-LN	Climatological, Low Navigability Scenario
C-ML	Climatological, Most Likely Navigability Scenario
C-NI	Climatological, No Ice Navigability Scenario
CAPEX	Capital Expenditures
CCG	Canadian Coast Guard
CNPC	China National Petroleum Corporation
DGPS	Differential Global Positioning System
EC	European Commission
EU	European Union
FEED	Front-End Engineering Design
FID	Final Investment Decision
FSRU	Floating Storage and Regasification Unit
FTA	Free Trade Agreement
GCM	General Circulation Model
GSIM	Global Simulation (model)
GSP	Global Positioning System
IMO	International Maritime Organisation
INSTROP	International Northern Sea Route Program
LNG	Liquefied Natural Gas
MARPOL	Maritime Pollution (act)
MT	Million Tonnes
MTPA	Million Tonnes per Annum
NEP	Northeast Passage
NSR	Northern Sea Route
NSRA	Northern Sea Route Administration
NWP	Northwest Passage
OPEX	Operational Expenditures
OW	Open Water (vessel)
PC	Polar Class
RCP	Representative Concentration Pathway
SD	Standard Deviation
TEU	Twenty-Foot Equivalent Unit (Container)
TPP	Transpolar Passage
UK	United Kingdom
UNCLOS	United Nations Convention Law Of The Seas
US	United States
USD	United States Dollar
USCG	United States Coast Gua

1. Introduction

Since day and age sailing routes through the Arctic have been the dream of many western traders to enjoy a shorter route to the East. The many failed attempts, among which is the famous expedition by Barentz and Van Heemskerk which involved the forced wintering on Novaya Zemlya in the Kara region, did not melt the dream of transarctic shipping. As global temperatures have been rising over the last century icecaps have been melting and as a result of that, transarctic shipping routes again captured the attention of opportunistic actors in the maritime industry. Particularly LNG shipping, due to it's high value and time sensitivity, is considered as a high potential cargo for transarctic shipping. In the case of the Northern Sea Route, the length of the available shipping routes passing through Russian Arctic waters are reduced approximately by 40% in comparison to the conventional route transiting the Suez Canal. As sea ice further retreats, shipping routes closer to the North Pole become feasible with ultimately the transpolar route being the shortest possible route from Europe to Asia. The Northwest Passages pass through the Canadian arctic, being in terms of distance attractive for cargoes moving from Northwest to Northeast America and Europe (and vice versa), is possibly competitive to the Panama Canal. Besides distance, other benefits such as avoidance of piracy risk and transit dues may be present for the routes. On the other hand is shipping in the Arctic is associated with higher vessel building, operating and insurance costs, as well as the requirement for icebreaker assistance.

It is expected that between 2030 and 2040 the first ice-free summers can be observed and the Russian Federation is investing heavily both in Arctic infrastructure, in terms of icebreakers, pilotage and other adjacent services, as well as Arctic oil and gas exploration. It is estimated that the Arctic holds 13 percent of the worlds unexplored oil reserves and 30 percent of the world natural gas reserves (Miller, 2014).

When natural gas is cooled down to a temperature of -163 °C it is liquefied (LNG) and reduces in volume by a factor 600. This reduction in volume makes of the gas economically attractive for shipping. Economically LNG shipping is highly dependent on speed during the voyage, as the cargo absorbs warmth from the surface area of the tank, the cargo evaporates. LNG carriers are therefore generally designed for sailing speeds around 20 knots opposed to other bulk carriers that generally sail at speeds around 12-14 knots.

Several studies have been performed to assess the feasibility of commercial use of the Arctic routes, for LNG as well as for other cargoes. Research concludes that there is great potential for commercial use of the NSR and to a lesser extent the NWP. However, given economic feasibility, research on the economic impact of open Arctic routes is nearly absent. Knowledge on economic impacts is relevant, for business as well as other stakeholders, to understand the scope of it's potential and to whom the Arctic routes are relevant.

This research aims at assessing the economic impacts of open Arctic shipping routes on global maritime LNG trade in terms of possible deviations in trade patterns, prices, traded values, relative use of sea routes and welfare effects. The research question is therefore stated as follows:

What is the economic impact of open Arctic routes on global maritime LNG trade?

For the analysis of this research question, we use the Global Simulation (GSIM) Model to simulate LNG trade for 2040 after a certain extent of openness of the Arctic routes represented by three feasible scenarios; ‘low navigability’, ‘high navigability’ and ‘most likely navigability’. To put these scenarios further into perspective a fourth navigability scenario is added where zero sea ice is assumed.

The four navigability scenarios are mapped onto two main scenarios; the climatological and the aggregated scenario. In the climatological scenario, trade flows according to current facilities of supply and demand are used for the base case. The aggregated scenario takes into account new production and import capacity estimated for 2040 creating several different regions among which the Kara region in the Russian Arctic as an export hub, a strong increase of Australian LNG production and the shift for the US from importer to exporter. The distinction between these two scenarios allows us to observe the impact of the geographical distribution of supply and demand on the use and effect of the Arctic routes.

The research is structured as follows: First, climatological forecasts are assessed to later generate composite forecasts on the level of sea ice and length of the navigable season. Secondly, the infrastructural requirements, history of development, current state of infrastructure, geopolitical factors and current cargo volumes are assessed to develop an indication to what extend the infrastructure will be able to support commercial shipping in the future. Then, in the third chapter, attention is directed to the LNG market, giving an overview of primarily supply, demand, future capacity and forecasts. Thereafter the aforementioned methodology is performed after which the findings are presented.

2. The Arctic Routes

2.1 Definition

The Arctic Circle is an important geographical limit since at this latitude places experience 24 hours of light once a year. Moving closer to the North Pole the days of continuous light increase until one reaches the Pole where it remains light for six months each year. Vice versa, for the other months continuous dark is experienced and this decreases in time as one moves away from the North Pole. This seasonality determines the growth and meltdown of ice in the Arctic Ocean and Arctic Seas. With 14.056 square kilometres the Arctic Ocean is the smallest of the five oceans. It borders with several coastal seas, which are all seasonally covered with sea ice (Arctic Council, 2009). The Arctic routes consist of two, not exactly defined, shipping lanes that cross the Arctic Seas connecting the Atlantic Ocean with the Pacific Ocean.

The Northern Shipping Route (NSR), previously referred to as the Northeast Passage (NEP), consists of the shipping routes that connect the Atlantic Ocean with the Pacific Ocean along the Russian coast of Siberia and the Far East. It crosses five Arctic Seas; The Barents Sea, the Kara Sea, the Laptev Sea, the East Siberian Sea and the Chuckchi Sea. The NSR is considered to range from 2100 and 2900 nautical miles depending on the choice of routes, which is mainly determined by the distribution of sea ice (Liu and Kronbak, 2010).

The Northwest Passage (NWP) consists of the shipping routes that connect the Atlantic Ocean with the Pacific Ocean along the northern coast of North America along the Canadian Arctic Archipelago. There are five to seven seaways through the Canadian Archipelago among which are the McClure Strait, the Prince of Wales Strait and the Baffin Bay via the Davis Strait, which is the only one suitable for large vessels (Kittagawa, 2008). In appendix 1 and 2 a more detailed map of the arctic waterways is shown.

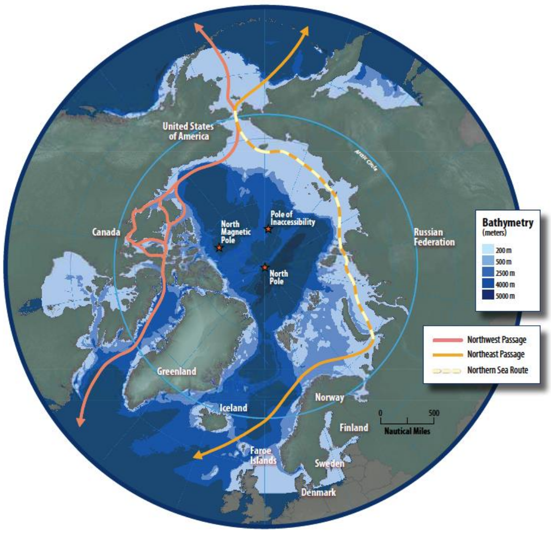


Figure 1: Arctic Routes. **Source: Arctic Council (2009)**

2.2 Arctic Ice Conditions, Navigability and Forecasts

The ice in the Arctic comes in different types and shapes. Most of the ice is sea ice, which is frozen sea surface but also icebergs that originate from land may drift around. Young ice is less than 30 centimetres thick and generally does not generate safety issues for vessels. First-year ice grows easily to about one meter in thickness but rarely thicker than two meters and is generally soft due to air pockets. Ice strengthened vessels are in most cases strong enough to cope with this type of ice. Old ice is first-year ice that has survived summer, is extremely hard since during summer the air pockets drain out the bottom and allow solid ice to grow back. Old ice is one to five meters in thickness. Old ice is a serious risk, even for ice class vessels. The ice is harder than concrete and under pressure it can stop the most powerful icebreakers. Lastly, icebergs are large masses of floating ice. They are very hard and dangerous to vessels. Smaller icebergs are called bergy bits or growlers and are very dangerous since they are difficult to spot (Arctic Council, 2009).

Although there are many different projections of the sea ice it is evident that, on average, the coverage of sea ice has been decreasing over the last decades. In 2004, the Arctic Climate Impact Assessment expected ice-free summers in 100 years (recent expected ice-free summers) with an increase in available unescorted sailing days from 30 to 120 for current ice-class vessels and 170 days for new generations of ice class vessels (Ragner, 2008).

More recent studies indicate a more rapid retreat of sea ice. Xu et. al. (2011) found that the National Snow and Ice Data Center reported the lowest ice extent record in September 2007 of 4.13 million square kilometres, 39% under the mean level. In 2012 this record was beaten with a total coverage of 3.6 million square kilometres (Haeffelé, 2013). Especially in the eastern part of the Russian Arctic seas, the ice retreated more rapidly than initially expected which has opened the Longa Strait in September since 2002. The Canadian Arctic is likely to open up less extensively since the ice is land fast longer periods due to the series of islands which protect the ice form movement by wind and warm ocean waters in summer (Howell et. al., 2008).

Recent projections on climate change scenarios have been analysed by Smith and Stephenson (2013). They have made efforts to answer the question how geophysical changes in sea ice will realistically impact optimal shipping routes in the Arctic. In doing so, they analysed seven different climate model projections of sea ice, assuming two different climate scenarios and two different vessel classes, Polar Class 6 and regular open water vessels (See section 3.3.2 for classification details), at present (2006 – 2015) and by mid-century (2040 – 2059), for the month September. Previous studies lacked in combining climate model output with numerical transportation analysis, Smith and Stephenson (2013) closed this gap by applying the Arctic Transportation Accessibility Model.

They used two climate change scenarios RCP4.5 (+4.5 Watt/m^2) and RCP8.5 (+8.5 Watt/m^2) and seven general circulation models (GCM). RCP stands for 'representative concentration pathway' and is the most recent generation of scenarios that is used as input for climate change models. The change in radiative =forcing, Watt/m^2, is the difference in energy that enters the atmosphere and is returned to space compared to the pre-industrial situation (Bjørnaes, 2014). The RCP4.5 scenario thus assumes an increase of 4.5 watt per square meter to remain within the atmosphere compared to pre-industrial levels. General circulation models are used to make estimation on how the climate is likely to evolve under an assumed RCP scenario.

Smith and Stephenson (2013) computed optimal navigation routes using a least-costs path algorithm for the two RCP scenarios and two ship classes. They found that by mid-century the overall navigation potential is likely to have increased substantially while the present case largely replicated current conditions. The following three important conclusions have been drawn:

First, the feasibility of regular open water (OW, blue tracks) vessels increased in frequency and numerous optimal routes shifted northward away from the Russian coastline. The ice limited the probability of a technically feasible OW transit in the base case to 40% but the probability increases to 61%-71% for 2006 – 2015 and to 94%-98% for the mid-century case. Second, new optimal navigation routes for Polar Class 6 vessels (red tracks) through the central Arctic Ocean is evident by mid-century. Third, the NWP has the lowest navigation potential but opens up substantially by mid-century.

For vessels of any class to and from Europe it is most optimal to navigate along the NSR. Vessels from North America are able to enjoy a 30% reduction in distance by using the NWP over the NSR by 2040 – 2059 (Smith and Stephenson, 2013) and a transit from Vancouver to Finland saves 1000 nautical miles using the NWP instead of the Panama Canal (Neuman, 2013), a reduction of 10% (Vesseldistance.com, 2014).

The results of the research by Smith and Stephenson (2013) need to be interpreted with caution since they have based the research only on reductions in ice thickness, concentration and on geographical distance, for the peaking month September. They have not taken into account the infrastructure, regulations, economic aspects and bathymetry.

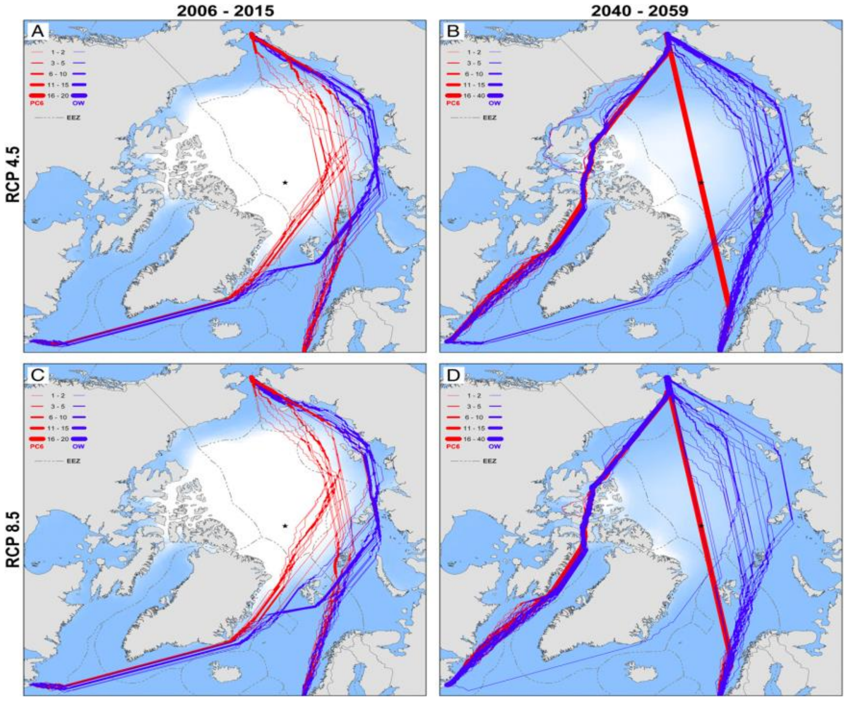


Figure 2: Optimal Routes September. **Source: Smith and Stephenson (2013)**

Stephenson et. al. (2013) made effort to quantify the length and variability of the NSR navigation season as constrained by both sea ice and bathymetry over the next fifteen years under a minimum forcing scenario (RCP6). Aside ice thickness, bathymetry is a key constraint for navigation in certain areas of the NSR since draft restrict the route choice. The Dmitry Laptev Strait (6.7m) and Sannikov Strait (13m), both between the New Siberian Islands are especially shallow. Ports along this regions coastal route can handle vessels with a draft up to 9m and directly north of the New Siberian Islands the vessels may have a draft of 12.5 meter. Other large straits generally do not restrict navigation based on bathymetry (Stephenson et. al., 2013).

Polar class 3	Barents		Kara		Laptev		East Siberian		Chukchi	
January	**30**	1	**28**	2	**23**	7	**24**	7	**28**	3
February	**27**	1	**26**	2	**21**	5	**20**	7	**24**	3
March	**30**	1	**28**	1	**22**	6	**17**	10	**23**	5
April	**29**	1	**25**	2	**18**	7	**13**	9	**18**	6
May	**29**	2	**24**	3	**15**	8	**13**	9	**19**	7
June	**28**	1	**24**	3	**14**	9	**14**	9	**23**	6
July	**30**	1	**27**	3	**20**	10	**22**	9	**29**	4
August	**30**	1	**29**	3	**24**	8	**27**	5	**31**	0
September	**30**	1	**29**	2	**27**	5	**28**	5	**30**	0
October	**31**	1	**29**	2	**27**	5	**28**	4	**31**	0
November	**29**	1	**28**	2	**24**	7	**26**	5	**29**	1
December	**30**	1	**28**	2	**24**	7	**26**	5	**30**	2
Annual	**353**	8	**324**	21	**258**	75	**258**	68	**314**	31

Table 2: PC3 Average and SD of Navigable Days NSR 2013 - 2027 (RCP6). **Source: Stephenson et. al. (2013)**

Another study, performed by DNV (2010), assessed feasible transit routes for a 6500 TEU vessel with an icebreaking stern and for a 6500 TEU PC-4 vessel. Four routes, shown in figure 3, have been considered. Route 1 passes primarily through Russian territorial waters, route 2 avoids some of the shallow areas, route 3 passes mostly through areas outside Russia's territorial waters and route 4 goes directly across the North Pole. For vessels with an icebreaking stern DNV (2010) assumed all-year navigation over route 3 in every scenario while 100 and 120 unassisted sailing days for PC-4 vessels were assumed for the 2030 and 2050 scenario respectively.

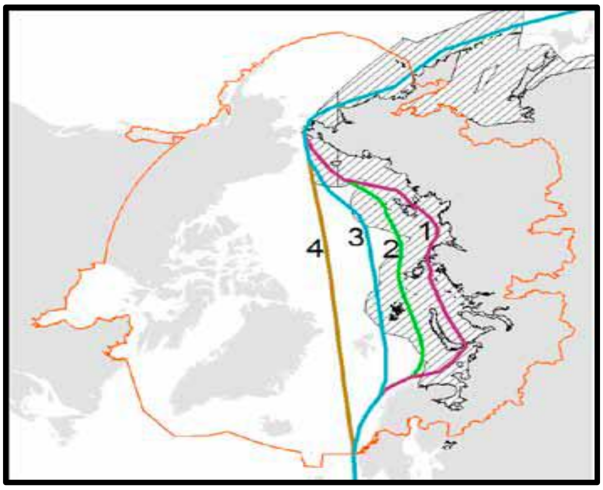


Figure 3: Navigiable routes 2030 – 2050. **Source: DNV (2010)**

Other projections on the accessibility of the arctic routes using different GCMs were made by Howell et. al. (2008), Francois and Rojas-Romagosa (2013) and Khon et. al. (2010) which had similar projections on the locations and extend of the retreat of sea ice.

2.3 Infrastructural Requirements

Haeffelé (2013) touched upon several fundamental challenges when navigating the Northern Sea Route. Issues concern the presence, thickness and density of ice, fog, whether the vessel is capable of following the icebreakers' track, the capability to cope with emergencies, pushing-off winds, pushing-to winds and moving ice blocks. The Arctic Council (2009) addressed the following environmental factors concerned with navigating in the Arctic; 'presence and movement of sea ice, icebergs, cold air and water temperatures, variable and unpredictable severe weather, magnetic variation, solar flare activity and extended daylight or night-time conditions'.

Large areas of the Arctic lack infrastructural quality to ensure safe navigation. This includes 'accuracy and availability of timely information needed for safe navigation, availability of search and rescue assets, pollution response assets and supporting shoreside infrastructure, port reception facilities for ship-generated waste, availability of deepwater ports, places of refuge and salvage resources' (Arctic Council, 2009). The Arctic Council (2009) also found that universal, mandatory and formal education and certification is required to supply skilled mariners.

Ho (2011) identified six general issues that need tie bee resolved for the reliability to use the NSR as a transit route. These requirements, logically, also apply to the Northwest Passage. The provision of meteorological, oceanographic and sea ice information through environmental monitoring and forecasting, Icebreaking and search and rescue service assets, experienced mariners, ship technology for independent vessel operations in ice covered waters, vessel tracking along narrow straits and an integrated governance and regulatory framework.

The Arctic Council (2009) and Ragner (2000) elaborated quite extensively on the infrastructural requirements and shortcomings of the Arctic infrastructure. The Arctic Council (2009) putting more emphasis on the NWP and Ragner (2000) covering solely the NSR. Although generally only mildly covered, infrastructure is widely considered as the second major determinant of feasibility for commercial use of the arctic routes. From the literature covered in this section, along with the papers by Kittagawa (2008) and Christopher (2008), the following general requirements can be derived. When looking at the individual subjects one could endlessly go into detail on the requirements and current state. Evaluation of the current state and shortcomings of the infrastructure will be covered in the sections on the NSR and NWP individually where the infrastructure will be discussed more in detail.

2.4 The Northern Sea Route

2.4.1 History and Development

In pursuit of new seaways to Asia, European countries, primarily Great Britain and the Netherlands, have set up expeditions since the 15th century to explore a sailing route towards the East (D'Anglure, 1984). Sailing distance over the NSR can result in as much as 40% distance savings over the Suez Canal route (Liu and Kronbak, 2011) and is three times shorter than the route around the African Cape. Initial goals were often abandoned when more accessible resources such as cod, whales and beavers were discovered (D'Anglure, 1984). It took until 1879 that a complete transit over the NSR was made for the first time. The Swedish-Finnish explorer Adolf Erik Nordenskiöld, departing from Europe, reached the Bering Strait after spending one winter on the way with the steamer 'Vega'. Nordenskiöld concluded that the route was too difficult to sail for commercial use. However, European trade did reach the Ob and Yenisey rivers in the Kara Sea sporadically (Ragner, 2008).

Granberg (1998) identified four stages of development; Up to 1932, Individual expedition sea voyages; 1932 to early 1950s, organisation of regular navigation and construction of a specialised fleet and ports; 1950 to 1970, transformation into a normally functioning line during summer-autumnal seasons and since the late 1970s, start of year round use of the NSR.

The development of the routes is mainly done by Russia and the Soviet Union. After the Russian Revolution in 1917, access to the Russian Arctic was restricted for non-Soviet vessels, the Kara routes were further developed by the Soviets to support the industrial development their Arctic recourses and settlements. A military role evolved when navy fleets were to be transferred from the Pacific to the Barents Sea in 1942 (Ragner, 2008). In the late 1970s powerful ice breakers and cargo ships were being put into operation and ports along the route were remodelled. Since the late 1970s regular year-round voyages were undertaken on the western part of the NSR (Grandberg, 1998). In the 1980s approximately 5 to 6 million tons of cargo was carried yearly along the NSR (Liu and Kronbak, 2010), these volumes were mainly driven by the development of natural resources (Kitagawa, 2008). However, after the Soviet Union seized to exist, the level of subsidies required to maintain the activities on the NSR could not be sustained and the cargo volumes disappeared (Ragner, 2008).

In October 1987, Secretary-General Gorbachev declared in a speech that the NSR would be opened for international traffic and in 1991 regulations were approved (Liu and Kronbak, 2010). However, cargo volumes decreased over the years and since the early 2000s Russia has neglected the NSR resulting in poor maintenance of ports and ageing of icebreakers. In 2008 the route opened for international transit during July and August and in 2013 the route was open from July to November. In 2012 there were, according to Russian authorities, 46 transits made with a total cargo volume of 1.2 million tonnes. The positive trend in commercial cargo volumes is expected to continue (Haeffelé, 2013).

2.4.2 (Geo)politics

After Gorbechev's announcement of opening the route, an international NSR knowledge base was created, the International Northern Sea Route Program (INSTROP) to investigate the potential increased international use of the route (Liu and Kronbak, 2010). Russia has been enthusiastically promoting its international use but claims sovereignty and jurisdiction over the route. As more indications show that the NSR will most likely become an important transit route and source of natural resources in the future, many countries are trying to get a stake in the Arctic among which are several non-Arctic states.

Russia's claims on sovereignty conflict with the statements made by the EU and the US, that the NSR passes through international straits. Also Asian countries, such as South Korea, Japan and China anticipate on the probability of the Arctic and the NSR to become an important maritime factor. So far, most parties have not actively challenged Russia's control (Blunden, 2012).

Countries try to increase and justify their influence in the Arctic region for a great part by conducting research. The main institution in the region is the Arctic Council, consisting of the US, Canada, Denmark, Iceland, Norway, Finland, Sweden and Russia (Arctic Council, 2009). It is does however have no decision-making power. The pursuit for power in the Arctic comes with risk of political tensions and could escalate into a new 'great game'. The European Union tried to join the Arctic Council but their bid has been rejected (Kefferpütz, 2010).

The European Commission has shown interest in gradually exploring and improving conditions for navigating in the Arctic. It emphasizes that member states should defend the right of freedom of navigation and innocent passage. The EC noted that possible future expansions of the Suez Canal result in larger vessels and more traffic in de Mediterranean resulting in bigger risks and acknowledges the importance of the NSR (Blunden, 2012). In 2008 five coastal states (Canada, Norway, Russia, The US and Denmark for Greenland), also referred to as the Arctic 5 or the A5, issued the Ilulisat Declaration, trying to insulate governance over the Arctic region (Keppferpütz, 2010). Obviously the EC, and especially Germany which is most passionately seeking influence, were alarmed by this declaration (Blunden, 2012).

As Europe's largest exporter with an expected increase in trade volumes, Germany is aware of the potential of the shorter trading route to Asia. German shipping companies already operate in western Siberia and the German shipbuilding industry is building relatively many ice class vessels. Since Iceland is due to its location, deep fjords and land availability is a good candidate as a strategic location for cargo and offshore activities in the Arctic, Germany is very supportive in negotiations to include Iceland as a member of the EU (Blunden, 2012).

Russia is very keen on strengthening and securing its influence in the Arctic and has led a very proactive policy for the region. The philosophy behind this is that moving fast will give Russia a competitive advantage to establish a strong position in the

Arctic. To quote Nikolai Patrushev, secretary of the Security Council, ‘if we do not move fast, we will be forced out’ (Schepp and Traufetter, 2009; Kefferpütz, 2010). In 2008 Russia’s strategy with respect to the Arctic is defined in their ‘strategy towards the arctic until 2020 and beyond’ and is divided into three main stages (Kefferpütz, 2010).

First (2008 – 2010), provide extensive scientific evidence of a justified claim, expand possibilities for international cooperation, establish a framework for the development of port infrastructure, high-tech industrial clusters and special economic zones in Russia’s northern regions. Second (2011 – 2015), invoke international legal recognition of Russia’s external borders and expand competitive advantages in the extraction and transportation of resources. Third (2016 – 2020), transform the Russian High North into the leading strategic resource base. In pursuit of these goals, the country intends to use all available means. Among which are increasing military and security presence but also actively cooperate in bilateral discussions (Kefferpütz, 2010).

Recently however, the diplomatic relations between Russia and primarily western (EU, US) economies has worsened dramatically. The Ukraine crisis, where Russia actively supported pro-Russian separatists, led to a changing perception of Russia’s role in the international community. This process accelerated drastically after the crash of passenger flight MH17 and the actions Russian separatists and Russia in the aftermath. Sanctions from western economies may influence investments in gas pipelines or financial justification of Russian (Arctic) gas exploration. The outcome of current tensions remains to be seen but uncertainties surrounding Russia’s relation with the West will always exist.

Although it is cautious in questioning the existing legal regime in the Arctic, Japan would like the Arctic to be considered as ‘common heritage of humankind’. In 2009 Japan applied for membership for the Arctic Council and since the country has the largest merchant fleet in Asia by flag, the importance of the maritime industry to the country is evident. It is currently funding research into Arctic-class tankers and, given the location close to the Bering Strait, hopes on becoming an alternative hub location to Singapore. Enthusiasm was encouraged when in 2011 a Japanese vessel, the world’s largest ice-class bulk carrier, made a transit through the NSR in half the time of the Suez Canal route saving approximately 22 days (Blunden, 2012).

China has great interests in the Arctic, both as a transit route as well as for the supply of raw materials. Although China has not made any firm statements yet on Arctic manners China watchers expect that in the future the country will try to claim a stronger position in the Arctic. So far, the country seems to defend the idea that the Arctic is common heritage of humankind but the possibility that China will make regional claims in the area should be considered. China has shown to be very keen in improving its bilateral relations with Norway and Iceland. Chinese planners have anticipated on the idea on building large Arctic-class vessels and a Chinese tycoon has announced intentions to acquire 300 square kilometres in Iceland (Blunden, 2012).

Concluding, Russia seems to be very enthusiast in developing the Northern Sea Route but political issues with respect to sovereignty play an important role. The development of the region might be accelerated by the competition for power. Russia initially seemed cooperative with other major players but a worsening diplomatic climate may result in a more isolated approach. This could negatively affect the potential of the Northern Sea Route as a transit route since political tensions invoke uncertainties.

2.4.3 Infrastructure

Although the NSR is more developed than the NWP, according to Arctic Council (2009) the Arctic region in general is underdeveloped in terms of infrastructure to ensure a safe transit.

In 2000, Ragner (2000) did a study on the current state and future potential of the NSR infrastructure. Although out-dated, it gives a good impression of what position the infrastructure came from. In 2000 the infrastructure was suitable for handling the volumes transported at that time but Ragner (2000) recognised the limitations with taking into account expected growth in cargo volumes. Most attention was given to the ice-class cargo vessels, icebreakers and ports and he touched shortly upon communication systems, navigational aids, ice-forecasting and emergency facilities.

Russia has the world's largest fleet of icebreakers with, in 2013, 37 icebreakers operational, 4 under construction and 8 more planned for future order. Ten of their operational icebreakers are nuclear powered, four of which, and one diesel powered have been to the North Pole. Most of the icebreakers are under the management of state owned company Rosatomflot (USCG, 2013) but there are also private companies providing piloting and icebreaking service. Among the newbuilds is the to be largest nuclear icebreaker in the world, the LK60. It is designed to navigate through three meters of ice thickness and has a power of 60 megawatts. It can adjust its draft between 8.5 to 10.8 meters and has a maximum design width of 34 meters. This is four meters wider than the class of icebreakers it will replace (World Maritime News, 2012). According to World Maritime News (2012), this class of icebreakers is 'exactly what Rosatomflot needs to open the Northern Sea Route for commercial traffic all year around'. The prototype is planned to be ready for delivery in 2017 and two subsequent vessels are ordered for 2019 and 2020 at a total contract value of 2.3 billion dollars (Pettersen, 2014). Aside from icebreakers, there are large building plans by different parties for ice strengthened LNG carriers.

With respect to communication two main systems based on geostatic satellites are used, the international INMARSAT and the Russian OCEAN system. However, since only few of the INMARSAT receivers were compatible with the OCEAN system there was a critical communication gap. INMARSAT satellites face a coverage gap in the Laptev Sea and north of Severnaya Zemlya while OCEAN has better coverage in the eastern Laptev Sea (Ragner, 2000). Kvamstad (2014) argued that the geostatic satellites have little or no coverage at all and that the sharp angles make them more vulnerable for disruptions external influences. The only satellite that fully covers the Arctic is 'Iridium' but systems disconnects occasionally which results in a connection gap of several minutes. Digital navigation charts are all considered to be sufficiently in order and published in Russian as well as in English (Ragner, 2000).

With respect to coastal navigation the NSR, an efficient system of coastal navigation aids have been developed. Since the Russian Arctic is relatively low and flat and therefore difficult to detect, highly accurate positioning systems are required. This includes radio beacons, lighted landmarks and lighthouses, sea daymarks, radar responder beacons, passive radar reflectors and buoyancy obstruction beacons. Especially dangerous areas are well equipped with navigational markers. The GPS system has a 95% accuracy to position vessels within at least 100 meters. A differential mode (DGPS) is 95% accurate to 10 meters and the complete coastal line should be covered by DGPS after 2000 (Ragner, 2000).

The Marine Operations Headquarters manages search and rescue operations, which is a subsidiary of the Northern Sea Route Administration (NSRA). These institutions will be covered in the next section. In 2000 there little yards available, which could only do minor repairs on relatively small vessels. Also no adequate salvage operations were possible (Ragner, 2000). Although there are several ports on the NSR, the absence of repair locations and the capacity to accommodate for vessels in distress is still an issue. Also adequate infrastructure in terms of weather stations is lacking. Also there is not an effective system to prevent and enact on oil spills and other industrial disasters (Arctic Info, 2013). Although the latter is more aimed at the exploration of natural resources in the area, there also needs to be such a system in place for merchant shipping. It is planned that 10 emergency rescue centres will be set up in the Arctic region, mainly in regions with much industrial activity (Arctic Info, 2013).

With respect to formal training of arctic maritime personnel and the adaption of unified classification the IMO is making efforts to develop a ‘Polar Code’. It covers design, construction, equipment, operational, training, search and rescue and environmental protection issues relevant to vessels operating in the Arctic regions (IMO, 2014). Since there are many aspects of the proposals that required lots of negotiation before agreements were made it has taken a long time for it to complete. The current completion is scheduled in 2014 and changes will go into force in 2016 (Eason, 2014).

In conclusion, the infrastructure of the NSR has been neglected for years but since the retreat of the ice and the increasing potential of the NSR as a transit route and especially as an exploration site for raw materials. Russia is heavily investing in its icebreaker fleet as well as other infrastructural aspects in order to meet requirements and cope with future cargo volumes. Although some argue that the revival of the Russian Arctic Routes is ‘at least 10 years away’ (Vukmanovic and Koranyi, 2013), on the longer run we can expect further development and better service for transiting vessels.

2.4.4 Institutions and Transit Regulations

The Russian Federation regulate shipping in the Arctic under article 234 of the 'UN Convention on the Law of the Seas' (UNCLOS) which allows coastal states to adopt special regulations for the Arctic region. In 1990 Russia adopted 'Regulations for Navigation on the Seaways of the Northern Sea' which has been revised in 1995. Priority is given to preservation of the maritime environment and these regulations are therefore stricter than MARPOL. Application for navigation is required at the NSRA, which assesses safety and environmental aspects. For example, a ship's inspection is required, at least two pilots need to be taken on board, the crew size must be sufficient to allow for a three-shift watch and the master is required to have a minimum of 15 days sailing experience in ice conditions (Arctic Council, 2009).

The Rules for Navigation on the Seaways of the Northern Sea include the following critical aspects (Chernova and Volkov, 2010); Borders of the Northern Sea Route, types of pilotage, a list of required documents, technical requirements and standards, information about transit dues, inspection procedures, regulation for icebreaker and pilot guidance and requirements for design, equipment and supplies.

The Northern Sea Route Administration (NSRA), a department of the Russian Ministry of Transport, manages compliance with these rules and aims on ensuring safe navigation and protection of the NSR marine environment. The main functions of the NSRA are obtaining and considering the submitted applications and issuing the permissions for navigation through the Northern sea route, issuing the certificates of the ice conventional pilotage on the Northern sea route, researching weather, ice, navigational and other conditions on the Northern sea route, coordination of installation of navigational aids and harmonization of regions to carry out hydrographic surveys operations on the Northern sea route, assistance in the organization of search and rescue operations in the water area of the Northern sea route, assistance in eliminating the consequences of pollution from vessels of harmful substances, sewage or garbage, rendering the information services in relation to the water area of the Northern sea route, making recommendations about development of routes of navigation and using icebreaking fleet in the water area of the Northern sea route, ice and navigational conditions there, timely data retrieval from Russian hydrometeorological service about hydrometeorological forecast and ice analysis (NSRA, 2014).

In 2013, the Russian Ministry of Transport adopted the most recent version of regulations under the title: Rules for Navigation in the Water Area of the Northern Sea Route (Ministry of Transport of Russia, 2013). Applications for navigation are considered within 10 working days since reception and in the case the NSRA refuses permission the applicant is informed by email with the reasons of refusal (Ministry of Transport of Russia, 2013).

The Russian government sets a tariff ceiling and ice breaking and piloting companies may set their tariffs as long as it does not exceed the ceiling. The tariff is set for the summer-autumn period (1 July – 30 November) and the winter-spring period (1 December – 30 June) and is dependent on the tonnage, the amount of transit zones passed (see Table 1) and the class of the vessel (Novikov, 2014a). Russia applies it's own classification for the vessels: 'The Ice class of a vessel is determined in accordance with the classification of the Russian Maritime Register of Shipping' (Nvikov, 2014b).

PILOTAGE ZONES NORTHERN SEA ROUTE	
The South-Western part of the Kara Sea	68º35' East longitude in the West 79º00' East longitude in the East
The North-Eastern part of the Kara Sea	79º00' East longitude in the West 105º00' East longitude in the East
The Western part of the Laptev Sea	105º00' East longitude in the West 125º00' East longitude in the East
The Eastern part of the Laptev Sea	125º00' East longitude in the West 140º00' East longitude in the East
The South-Western part of the East Siberian Sea	140º00' East longitude in the West 160º00' East longitude in the East
The North-Eastern part of the East Siberian Sea	160º00' East longitude in the West 180º00' East longitude in the East
The Chukchi Sea	180º00' East longitude in the West 168º58'37'' West longitude in the East

Table 2: Pilotage Zones Northern Sea Route. Source: Novikov, 2014b

In conclusion, the regulatory framework of the Northern Sea Route has developed extensively over the last decennia and provides shipowners with clear information about the requirements for transit and governing institutions. The applications are considered in a reasonable time frame and based on clearly defined requirements. Complications might occur in the case of classifying the vessels since Russia uses it's own classification framework while internationally uniform classifications still does not exist. However, after introduction of the IMO Polar Code in 2016 most issues around regulative imbalances will most likely be solved.

2.4.5 Current Cargo Volumes

In 2013 a total of 71 transits were made of which was the LNG carrier 'Arctic Aurora', owned and operated by Dynagas. The Arctic Aurora has an A1 (PC-7) ice classification, a gross tonnage of just over 100.000 and has a cargo capacity of 155.000 cbm. It made the transit from Hammerfest, Norway to Futtsu, Japan. The transit took place from 22 September until 6 October, spending 14,7 days at the Northern Sea Route and traveling an average speed of 7,1 knots (NSR Information Office, 2014).

One year earlier a total of 46 transits were made and Dynagas made the first LNG transit ever over the NSR ever with the 'Ob River', a vessel of similar size and with the same ice classification. It departed the November 8th from Hammerfest to arrive the 16th of December in Tobata, Japan. Having spent a total of 9 days on the NSR the Ob River travelled an average speed of 12,5 knots (NSR Information Office, 2014) and was guided by two nuclear icebreakers and had two pilots on board (Haeffelé, 2013).

2.5 The Northwest Passage

2.5.1 History and Development

Although not as enthusiastically developed as the Northern Sea Route, opening the Northwest Passage has been a goal for many explorers over history. Europeans have made expeditions to Iceland and Greenland since 325 B.C., but it was not until the 1490s that they started exploring the NWP as an alternative route to Asia. It took eventually until 1906 until the Norwegian explorer Roald Amundsen made a complete transit. It took him three winters to complete the journey. In the ages between, the primary driver of activity in these waters was whaling (Arctic Council, 2009).

From the end of the Second World War until the late 1960s the main driver for navigating the NWP was Canadian and U.S. national security. During the Cold War the Distant Early Warning line was constructed; a chain of communication and radar systems spanning 3000 miles from the northwest coast of Alaska up to Greenland. During the construction over 300.000 tonnes of cargo have been transported over the NWP. Since many vessels were not suited to navigate through the ice, the American Military Sea Transportation Service initiated a construction program for Arctic vessels (Arctic Council, 2009).

The first commercial vessel to cross the passage was the SS Manhattan in 1969, an oil-super tanker refitted with an ice-breaking bow and under surveillance of a Canadian icebreaker. Although the journey was successful, the risk and impact of pollution was considered to be too high and there was eventually decided on the Trans-Alaska Pipeline for the transportation of oil (Kitagawa, 2008).
As a result of global warming, in August 2007 the NWP became accessible to ships without the guidance of an icebreaker and at least three vessels made a successful transit. The European Space Agency announced that the passage had opened for the first time since records were made. This has reclaimed interest in the passage for commercial use. The passage lacks however in infrastructure to make this a viable commercial sailing route (Kitagawa, 2008). In section 2.5.3 there will be elaborated on the current state and investment requirements with respect to the infrastructure of the Northwest Passage.

2.5.2 (Geo)politics

Aside from the general geopolitical issues covered in section 2.4.2 the Northwest Passage is subject to another, more specific, dispute over sovereignty. Canada claims the Northwest Passage is part of its historic internal waters while the United State considers it as an international strait (Elliot-Meisel, 2009). Although the legal dispute already existed since the 1880s, the discussion was seriously brought into play since 1985 when the US informed the Canadian government that the USCG icebreaker ‘Polar Sea’ would transit the Northwest Passage. The US invited the Canadian Coast Guard to participate in the transit. In response Canada stated that the Nortwest Passage is part of Canada’s internal waters but that it was committed to facilitate navigation through the NWP. After the transit of the ‘Polar Sea’, Canada reinforced their sovereignty in the area by drawing straight baselines connecting the outer lands of the archipelago and defining the outer limits of Canada's internal waters. Objections were only made by the US and by the European community (Byers and Lalonde, 2009).

Although both countries have sound legal arguments that are supported by the International Court of Justice, a strictly legal solution to the NWP is unlikely (Charron, 2005). Security concerns with respect to the NWP are shared by the US and Canada. Although this requires effective presence in the area, Canada is still poorly equipped in this manner. The US and Canada are close partners with respect to border security in the North but the US still does not recognise Canada's claim for sovereignty. The major reason is that if the US does so, they face the risk that other countries bordering straits and channels could arbitrate for imposing their own regulations with respect to navigation (Byers and Lalonde, 2009).

2.5.3 Infrastructure

Especially in the Canadian archipelago good infrastructure is lacking. In 2008 still most transportation for Arctic communities have been done by air and since the announcement of the Panama Canal expansion the pressure to open up the NWP for shipping has decreased. Also the construction of port facilities has been very limited and efforts to improve communication and information technologies in the region has been motivated by connecting the communities rather than from a shipping perspective (Christoper, 2008).

In 2007 the Canadian prime minister announced the refurbishment of an existing deep-water wharf on northern Baffin Island for refuelling and support to the navy and coast guard. He also announced that six to eight ice-class patrol ships would be built. Also 900, to a total of 5000, part-time reservists will expand the Canadian Ranger program. Many of them are Inuit and other locals equipped with snowmobiles to fulfil search-and-rescue and surveillance functions in their living area (Byers and Lalonde, 2009). These developments however seem to be little focussed on accommodating commercial shipping but rather strengthening in the sovereignty discussion and to support growing regional (maritime) activities.

The existing Canadian icebreaker fleet is aging, underperforming and not designed to assist commercial vessels. Also good charts of bathymetry are lacking and the GPS system has of course the same coverage issues as discussed for the Russian Arctic (Penty and Dmitrieva, 2013). Canada has to come from much farther with respect to infrastructural development (i.e. investments) than Russia. Combined with the fact that the ice conditions in the Canadian archipelago are less favourable and that less capital is available, it is questionably to what extend the Canadian government will follow trough with the infrastructural development required for commercial shipping. Investments will likely have to come from private investors (Penty and Dmitrieva, 2013) meaning that, unlike the NSR, there is less allowance for the unprofitable start-up period, which can be very extensive with the risk of the NWP not being able to compete with the NSR and Panama Canal at all.

With respect to the US Arctic there are also major shortcomings. First of all, the icebreaking fleet is aging, underperforming and at risk of not being able to support current national interests in the arctic regions (Elliot-Meisel, 2009). There are no deep-water ports in the US Arctic but research for the development of a deep-water port in north Alaska is being done. Aside the two in operation now, a new USCG icebreaker is planned to be build for operations in 2020, which will be used for emergency response, research assistance and patrol. New nautical maps for parts of the US Arctic are being made but there are no current plans to expand the aids of navigation in the region and good weather forecasting facilities are also lacking. With respect to the industry perspective, little shipping companies expect to use the NWP as a transit route. Besides the fact that the infrastructure is lacking, they show greater interest in the NSR since the NWP is more difficult to access for larger vessels due to shallow waters and is less reliable due to harsher ice conditions (GAO, 2014).

2.5.4 Institutions and Transit Regulations

The Canadian and US Coast Guard regulate shipping in the Canadian and US Arctic respectively. Construction and navigation aspects are governed by the Arctic Shipping Pollution Prevention Regulations, the Canada Shipping Act and several other legislations, which aim to prevent pollution and ensure safety of navigation. This includes the need for ice navigators, pollution prevention and other certificates, icebreaker assistance etc. Canada embraces the development of the IMO Polar Class regulations and PC vessel classification. The Canadian Arctic is divided into Safety Control Zones shown in figure 4. Zone 1 contains the most harsh ice conditions and zone 16 the least. For PC6 vessels there is only a one-month window, 15th of August to the 15th of September, of allowable entering days (Canadian Coast Guard, 2012).

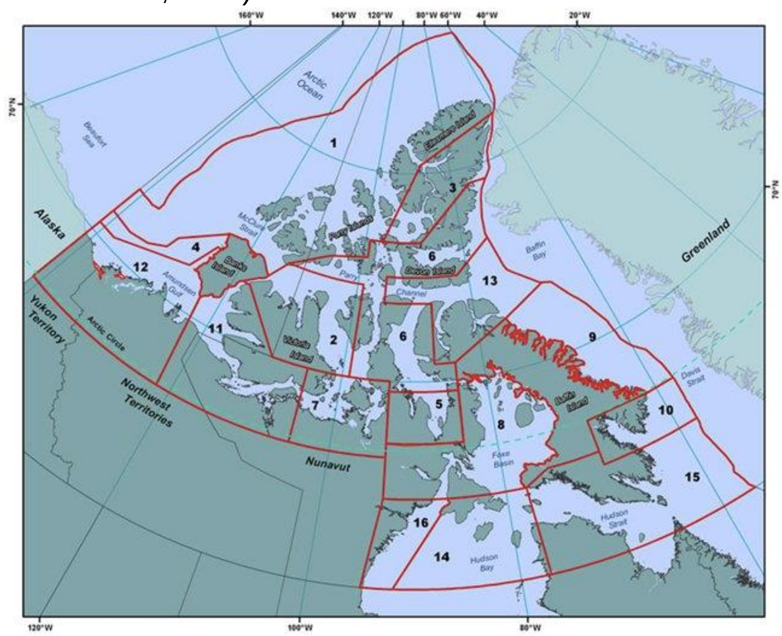


Figure 4: Safety Control Zones Canadian Arctic. **Source: Canadian Coast Guard (2012)**

There is no fee system for the NWP and although the Canadian Coast Guard monitors shipping in the region, there have been vessels that navigated the NWP without knowledge of authorities. Currently the Coast Guard does not charge fees for assistance and according to Eger (2010), Canada is not likely to impose fees in the (near) future to encourage future shipping. An ice navigator costs $295 per day and icebreaker assistance costs approximately $50.000 per day, which is currently at the expense of the CCG (Weber, 2014). It is assumed that in the future, when cargo volumes increase, the Coast Guard will charge on a cost-covering basis.

2.5.5 Current Cargo Volumes

So far, only one commercial cargo vessel has made a transit through the NWP. The 75,000-ton Nordic Orion sailed under escort of an icebreaker from Vancouver to a port in Finland carrying coal (Penty and Dimitrieva, 2013). According to the Danish operator the vessel was able to carry 15,000 more tons of coal than the Panama Canal would have allowed and would save $80,000 dollar in fuel cost over the 1000 nautical mile shorter route (Neuman, 2013). The voyage took place in September 2013 and the vessel had an A1 (PC-7) ice class. Penty and Dimitrieva (2013) wrote that the Nordic Orion saved six days of voyage time and had a total saving of $200,000 dollars including tolls. After the success the Danish operator is planning to use the route more often (Weber, 2014).

Although GAO (2014) found that there is little interest in the NWP from commercial shipping companies, which currently look at the NSR as the most promising alternative route, viability has been proven. Conditions would still be less favourable than for the NSR but the option of the NWP as a shipping route must not be ruled out.

3. The LNG Industry

3.1 LNG Defined

LNG is liquefied natural gas that is cooled down to a temperature of at least -161 degrees Celsius at atmospheric pressure. By liquefying the gas, the volume decreases by factor 600, making it economical for transportation. Especially for long distances (700 miles for offshore and 2200 miles for onshore pipelines) LNG is competitive compared to pipelines, which are inflexible and have limited throughput capacity. Natural gas is composed of several different hydrocarbons, primarily methane, and other molecules such as water and carbon dioxide. In order to prevent solidifying of components such as water and carbon dioxide when liquefying the gas, most non-methane components need to be removed. The gas that remains for liquefaction consists of about 95% of methane and when liquefied it's odourless, colourless, non-corrosive and non-toxic (Foss, 2012).

The LNG value chain can be broken down in four main stages; exploration, liquefaction, shipping and storage & regasification. Natural gas is often discovered in the search for oil and is extracted in a similar way. Gas fields are generally located, either offshore or onshore, away from current markets. After the contaminants are removed the gas is cooled by refrigerants. Storage is done in double walled storage tanks. The outer wall is generally made out of carbon steel and concrete while the inner tank is build with materials that enable a strong construction under lowering temperatures. The space in between the storage tanks is filled with insulation. In order to regasify the LNG, it is pumped through various terminal components where it is heated under a controlled environment (Foss, 2012). In section 3.3 there will be elaborated on LNG shipping.

The development of an international LNG market has taken off mainly because of the widespread use of natural gas in electricity generation. Gas fuelled power stations can be built relatively fast and have economic and environmental benefits over power stations that run on other fossil fuels.

3.2 The LNG Market

3.1.1 Characteristics

The LNG trading market primarily taking place on inelastic terms (Gkonis and Psaraftis, 2009) with 69% of total volumes characterised by long-term contracts (20 years plus). In the short-term market, Asian buyers made up 72% of the spot traded volumes in 2012 with Japan, Korea and India alone accounting for 61% (IGU, 2013). Motivation behind long-term contracts on the buyer's side is security of supply, and on the production side, commercial security for project financing. Buyers, especially in Asia, typically seem to be willing to pay a premium for a reliable source of supply (Poten and Partners, 2010).

With respect to pricing, the global LNG market shows a wide disparity. This is mainly caused by the differences in contractual formulas. US LNG prices are indexed on Henry Hub gas-on-gas prices while European prices (approximately 60% parity) and Asian prices (approximately 90% parity) are indexed to oil prices. Oil prices are currently relatively high compared to gas prices, which leads to higher LNG prices for oil-linked pricing. In 2009, US, UK and Spanish LNG prices were priced at respectively 43%, 53% and 73% of Japanese LNG prices (Poten and Partners, 2010).

As mentioned, LNG trade traditionally has been under long-term contracts. In 2005 only 5% of total volumes were traded on the spot market, which gradually increased to the current share of 31%. The major factors accounting for this increase in spot trading are (IGU, 2013);

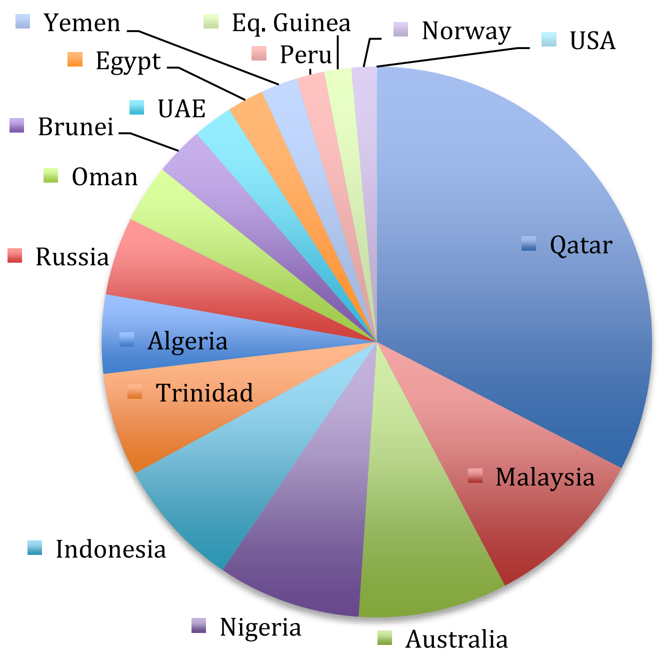
- A growth in contracts with destination flexibility
- Increase in number of exporters and importers
- Lack of domestic production in Japan, Korea and Taiwan resulting in a need for spot trades to cope with sudden changes in demand
- Continued great disparity in prices resulting in arbitrage opportunities
- Large growth of the LNG fleet
- Decrease in competitiveness compared to other fuels
- Large increase in demand in Asia and emerging markets

Hollins (2013) stated that the global market is increasingly becoming inter-connected and pricing is becoming inter-dependent. There is a growing complementary between European and Asian markets. As a result of the growing spot market, gas sellers are taking more price risk in Europe and in Asia this risk is generally taken at the buyer's side. In Europe suppliers enjoy increasing destination flexibility trough market diversification while in Asia buyers are moving upstream or to US markets to capture destination flexibility.

3.1.2 LNG Supply

Current situation

At the beginning of 2013 a total of 58 liquefaction plants existed and in 17 countries and 26 ports facilitated these exports (Clarksons, 2013). Qatar, already being by far the largest exporter, increased supply with 1.9 MT leading to a total share of 32.6% of global supply in 2012. Together with Australia (+ 1.6 MT) and Nigeria (+ 1.2 MT) they accounted for 75.6% of project specific supply growth in 2012. The following figures show the shares of LNG exports by country at the end of 2012 (IGU, 2013):



Country	m.t. Exports	share of world
Qatar	77.4	32.58%
Malaysia	23.1	9.72%
Australia	20.8	8.75%
Nigeria	20	8.42%
Indonesia	18.1	7.62%
Trinidad	14.4	6.06%
Algeria	11	4.63%
Russia	10.9	4.59%
Oman	8.1	3.41%
Brunei	6.8	2.86%
UAE	5.6	2.36%
Egypt	5.1	2.15%
Yemen	5.1	2.15%
Peru	3.9	1.64%
Eq. Guinea	3.8	1.60%
Norway	3.4	1.43%
USA	0.1	0.04%
Total	**237.6**	100.00%

Figure 5 and Table 3: LNG Exports in 2012 by Country. **Data: IGU (2013)**

In 2012 Angola was expected to join the club of LNG exporters (IGU, 2012) but due to delays in the construction of the LNG plant in Soyo the project was eventually commissioned in 2013. The plant is expected to be able to output 5.2 MTPA of LNG per year and it had its first cargo shipped in June 2013 (AngolaLNG, 2014). The plant is however still coping with technical difficulties resulting in a shutdown in April 2014 (UpstreamOnline, 2014).

Liquefaction Capacity and Future Supply

At the end of 2012 global liquefaction capacity was at 280.9 MTPA but a total of 110 MTPA capacity was under construction in 2013 and another 158 MTPA was at some stage in front-end engineering (FEED). Also 357 MTPA of liquefaction capacity had been proposed in 2013 and is under evaluation for investment. Global capacity is expected to be 366 MTPA by 2017. Australia will be the main driver of new capacity with seven projects under construction in 2013, accounting with 62 MTPA for 61% of all capacity that has reached the FID an is still the construction phase (IGU, 2013).

After Australia the US, with 18 MTPA liquefaction capacity under construction in 2013, has the largest expected growth in export capacity. According to IGU (2013) new liquefaction projects continue to be proposed almost monthly with a total of 180 MTPA capacity having not reached the FID. Most of these projects are located in the Gulf of Mexico (many of them are regasification terminals up for conversion). According to Clarksons (2013) it is unlikely that all these projects will actually be executed due to high financial cost of developing and the need for guaranteed buyers. However, the shale gas revolution did lead to a staggering increase in gas production leading to a drop in Henry Hub prices. With respect to energy exports, political issues have generally been restrictive but most liquefaction projects have obtained export licenses to countries with which the US holds a free trade agreement (FTA). Japan and other Asian countries are under FTA negotiations under the Trans-Pacific Partnership but non-FTA approvals are likely to come first (IGU, 2013). US exports are particularly competitive in Asian markets since prices are based on the Henry Hub gas-on-gas index while Asian contracts are based on much higher oil-indexes.

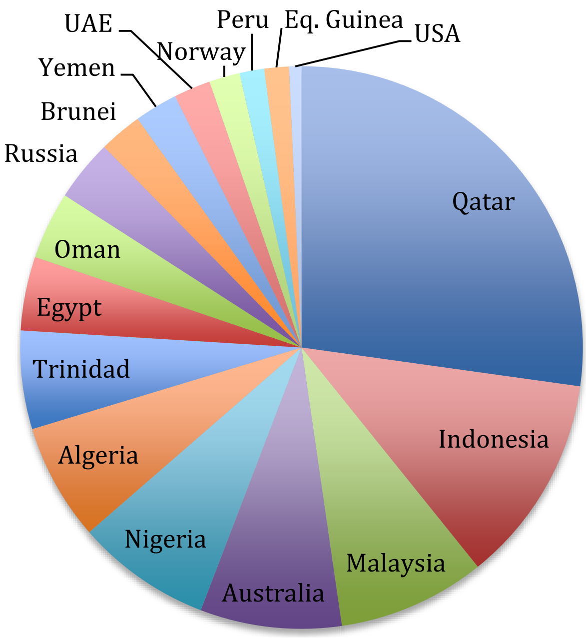
In Western Canada projects with a total capacity of 55 MTPA are proposed and Tanzania and Mozambique projects with a total of 30 MTPA capacity are proposed. The natural resources however could support an exploitation rate of more than 75 MTPA and domestic demand in these countries is low (IGU, 2013).

Major projects proposed in the Arctic are the two Yamal LNG projects, one under development by Russia's state controlled Gazprom and one by Russia's largest independent gas producer Novatek in partnership with Total and CNPC. The Yamal peninsula is located at the Kara Sea. Total expects a capacity of 16.5 MTPA. The project includes the commissioning of 16 ARC-7 (PC-4) LNG carriers (Total, 2014a). Gazprom's gas production forecasts for the Yamal peninsula and adjacent offshore areas are shown in the following table and the company is exploring the option of building a liquefaction plant (Gazprom, 2014).

Russia has lifted former legislation that prohibited other companies than Gazprom to export LNG and is planning to double Russia's share of global LNG exports by 2020. Aside the Yamal projects, there is a 15 MTPA project in Vladivostok scheduled for exporting the first cargoes in 2018. Also a smaller, 2.5 MTPA, plant is being developed at Indiga in the southeast part of the Barents Sea (Clarksons, 2013).

Another major Arctic LNG project is the Alaska LNG project. With an estimated cost between $45 and $65 billion it is among the largest natural gas development projects. It includes the construction of an 800-mile pipeline from Alaska's North Slope to a liquefaction plant and shipping terminal in Nikiski. The LNG plant would have a capacity of 20 MTPA. The project is still in the pre-FEED stage, which is expected to be finished in 2015-2016. The developers have recently requested a permission to export the LNG, which is currently under evaluation (ArcticGas, 2014).

Finally there are some projects in Africa either under construction or at development stages. Especially East Africa is considered as a potential export hub since large deposits have been discovered off Mozambican and Tanzanian coasts (Clarksons, 2013).



Country	Liquefaction capacity (mtpa)	share of world	Utilisation in 2012
Qatar	77	27.21%	101%
Indonesia	34	12.01%	56%
Malaysia	24	8.48%	97%
Australia	23	8.13%	92%
Nigeria	22	7.77%	91%
Algeria	19	6.71%	57%
Trinidad	16	5.65%	92%
Egypt	12	4.24%	42%
Oman	11	3.89%	75%
Russia	10	3.53%	114%
Brunei	7	2.47%	96%
Yemen	7	2.47%	77%
UAE	6	2.12%	96%
Norway	5	1.77%	77%
Angola			
Peru	4	1.41%	88%
Eq. Guinea	4	1.41%	104%
USA	2	0.71%	12%
Total	**283**	100.00%	84%

Figure 6 and Table 4: Liquefaction Capacity in 2012 by Country. **Data: IGU (2013)**

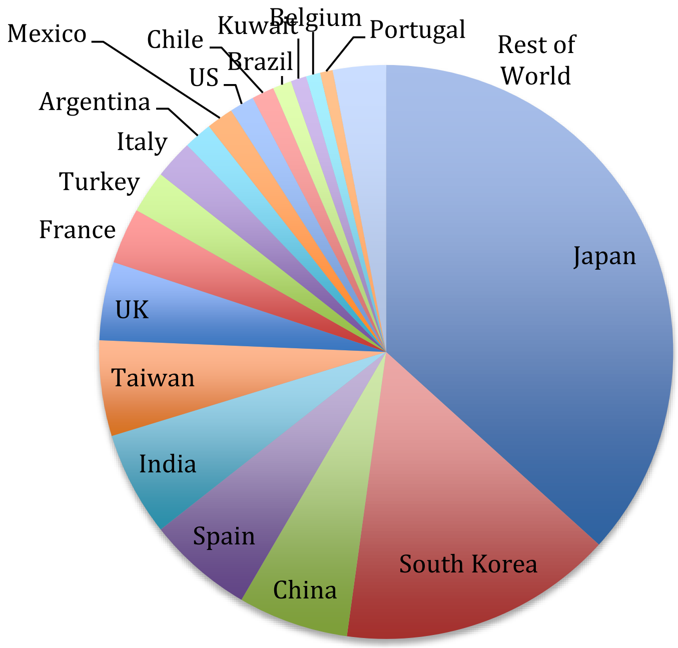
A map with locations of liquefaction capacity can be found in appendix 4.

3.1.3 LNG Demand

Current situation

Trade has grown very rapidly from around 100 MTPA in 2000 (Poten and Partners, 2010) to almost 240 MTPA in 2012 (IGU, 2013). In 2012, Japan (87.3 MT) and Korea (36.8 MT) were the largest importers of LNG worldwide accounting for 52% of the market. After the earthquake in 2011 that destroyed the Fukushima nuclear power plants Japan closed most of it's nuclear power generation capacity (43% in 2011 and another 89% in 2012) that accounted for 30% of power generation before the disaster and was brought down to just 3 % at the end of 2012. As a response LNG, that before the disaster fuelled 30% of Japan's power generation, was boosted as an emergency solution resulting in 12% higher imports in 2011 and an increase of 11% in 2012 (IGU, 2013).

Europe's share of global LNG imports fell by 20% as a result of increased competitiveness of coal, pipeline gas, renewable energy and weak economic growth.



Country	m.t. imports	share of world
Japan	87.3	36.71%
South Korea	36.8	15.48%
China	14.8	6.22%
Spain	14.2	5.97%
India	14	5.89%
Taiwan	12.8	5.38%
UK	10.5	4.42%
France	7.5	3.15%
Turkey	5.7	2.40%
Italy	5.2	2.19%
Argentina	3.8	1.60%
Mexico	3.6	1.51%
US	3.3	1.39%
Chile	3	1.26%
Brazil	2.5	1.05%
Kuwait	2.1	0.88%
Belgium	1.9	0.80%
Portugal	1.7	0.71%
Rest of World	7.1	2.99%
Total	**237.8**	100.00%

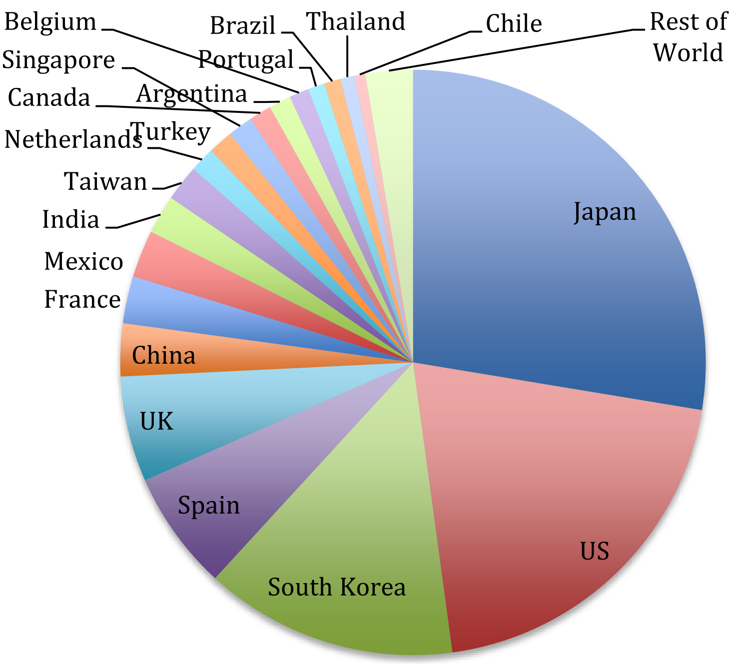
Figure 7 and Table 5: LNG Imports in 2012 by Country. **Data: IGU (2013)**

Regional distribution of global LNG demand is distributed as follows (IGU, 2013): North America (1%), Latin America (21%), Asia (46%), Europe (19%) and Middle East (6%).

Import Capacity and Future Demand

The last years a strong increase is countries that hold regasification capacity is observed. Between 2002 and 2012 the number of countries with LNG import capacity grew by 150% with half of these countries entering markets in the last two years. Singapore, Israel and Malaysia opened terminals in early 2013. At the end of 2012, 98 regasification terminals with a total capacity of 649 MTPA existed worldwide. Although at a slower pace, regasification capacity is still growing with new importers entering the market. In 2013, 23 terminals were under construction of which three were in countries that had never imported LNG before; Colombia, Lithuania and Poland (IGU, 2013).

Due to the seasonal nature of many gas markets, global utilisation of regasification capacity has always been under 50%. As a result of low demand in Europe and North America, utilisation fell to 37% in 2012. The US had a regasification utilisation rate of only 3% in 2012 due to the strong increase in domestic gas production since the shale gas boom. In Europe the drop was accounted for by substitution from coal, pipe gas and renewable energy (IGU, 2013). The low utilisation rate of US import terminals, together with the increase in liquefaction capacity, supports the global expectation that the US is becoming an exporter rather than an importer.



Country	Regas Capacity (mtpa)	share of world	Utilisation in 2012
Japan	180	27.61%	49%
US	132	20.25%	3%
South Korea	91	13.96%	40%
Spain	43	6.60%	36%
UK	38	5.83%	28%
China	19	2.91%	70%
France	17	2.61%	44%
Mexico	17	2.61%	20%
India	14	2.15%	103%
Taiwan	13	1.99%	98%
Netherlands	9	1.38%	7%
Turkey	9	1.38%	66%
Singapore	9	1.38%	0%
Canada	8	1.23%	63%
Argentina	8	1.23%	17%
Belgium	7	1.07%	52%
Portugal	6	0.92%	38%
Brazil	6	0.92%	50%
Thailand	5	0.77%	20%
Chile	4	0.61%	76%
Rest of World	17	2.61%	46%
Total	**652**	100.00%	37%

Figure 8 and Table 6: Regasification Capacity in 2012 by Country. **Data: IGU (2013)**

A map with locations of regasification capacity can be found in appendix 5.

According to Poten and Partners (2010) Asia Pacific LNG demand is expected to grow with an average of 2.7% per year in the period 2014 to 2035. IHS (2014) expected a reintroduction of Japanese power generation in 2014 but it is unlikely that Japan will ever return to pre-Fukushima levels of nuclear power generation. As a result of this reintroduction a slight decline in LNG imports in 2014 and 2015 and a steeper decline in 2016 and 2017 with eventually imports of less than 80 MT in 2018. However, over the past five years, China has quadrupled its capacity growing to 2.9% of global import capacity in 2012 and still planning to expand (IGU, 2013). Poten and Partners (2010) projected global LNG trade to reach more than 360 MTPA by 2020, 400 MTPA by 2025 and 270 MTPA by 2035.

As natural gas fields in Europe are depleting, gas imports into Europe are expected to increase. There are several projects designed to increase pipeline gas capacity into Europe, which are received with great interest due to interruptions of Russian gas supply and recent worsening diplomatic relations. The South Stream Pipeline would bring Russian gas into Europe via the Balkan, bypassing some transit countries. The Nabucco Pipeline (which is put on hold) and the Trans Adriatic Pipeline (completion expected in 2018) could bring Central Asian gas into Europe via Turkey. Even if all potential pipelines into Europe are built, it would not be sufficient to satisfy demand and shipping LNG would be the only solution (Clarksons, 2013).

The following table shows the expected growth in global natural gas demand according to Clarksons (2013):

NG Demand:	Compound Annual Growth Rate (2010 - 2040)	
OECD		1.0%
	Americas	**1.1%**
	USA	0.1%
	Europe	**0.1%**
	Asia	**1.3%**
	Japan	1.0%
Non-OECD		2.1%
	E-Eur/Eurasia	**1.0%**
	Russia	0.8%
	Asia	**3.1%**
	China	5.1%
	India	1.9%
	Middle East	**2.1%**
	Africa	**2.9%**
	Latin America	**1.9%**
	Brazil	3.7%
World		1.6%

Table 7: Expected Global NG Demand Growth 2010 - 2040. Source: Clarksons (2013)

3.3 LNG Shipping

3.3.1 Characteristics

Traditionally in LNG shipowners were integrated energy majors but recently also independent owners started to operate in the market. In 2009, 10% of the world fleet was under control of independent owners (Gkonis and Psaraftis, 2009). Some of these owners integrate and try to position themselves more upward in the supply chain, primarily by chartering out converted LNG carriers as floating storage and regasification units (FSRUs). In general shipping is a relatively weak link in the LNG chain and rates are not a major determining factor for final prices. Most power lays at the producers and to a lesser extend at the customers while shipping is, by nature, derived demand (Gkonis and Psaraftis, 2009). Shipping accounts on average for approximately 25% of the cost of the LNG supply chain (Stopford, 2009), but this percentage differs strongly among different markets due to a strong global imparity in LNG prices.

The LNG fleet, just like LNG trade, has historically been engaged on long-term contracts (time-charter). As a spot market is developing for LNG trade short-term charter fixtures followed. This is however still a fraction of total shipping demand. Since the market is primarily based on long-term time charters competition typically takes place when a charter expirers or when a new vessel enters the market. This makes the LNG shipping market less volatile compared to other bulk shipping markets (Clarksons, 2013).

An important aspect of LNG shipping is the boil-off or vaporising of the LNG. As the cargo absorbs heat from air and water surrounding the hull and cargo tanks, the LNG starts to vapour and tank pressure rises. Depending on the fuel system, the vapours are often used as fuel for the vessel but some vessels re-liquefy the gas. As the value of the cargo is relatively high and gets lost during the voyage, sailing speed is an important factor in LNG shipping. Therefore vessels are, unlike for example crude carriers, designed for higher sailing speeds and have a less bulky hull design. LNG carriers typically travel at 19 knots and have a cargo boil-off rate of 0.3% per day (Stopford, 2009).

3.3.2 The LNG Fleet

Containment systems

LNG carrier types are generally referred to by their containment system and size. The most common types of vessels are the Moss-type and membrane-type. They have a carrying capacity between 125.000 and 180.000 cubic meters (IGU, 2013).

The Moss type vessel has spherical, independent, single wall-storage tanks. The tank is supported by a vertical skirt, which runs though the centre of the tank, and is directly mounted on the deck foundations (Moon et. al, 2005). The membrane type vessels have one or more prismatic tanks. The insulation is integrated in the ship's hull and a membrane covering inside the tank is used for structural strength. The membrane type is the most common containment system and used in nearly 70% of the existing fleet and in 91% of the vessels on order (Clarksons, 2013).

The newest and largest generations of LNG vessels are the Qflex (21.000 – 217.000 cubic meters) and the Qmax (263.000 – 266.000 cubic meters) developed by QatarGas and have a membrane type containment system (QatarGas, 2014).

Propulsion

Currently the most commonly used propulsion system is the LNG fuelled steam turbine. The vessel uses it's own cargo to fuel (primarily boil-off gas) to power the engines. However, the high value of LNG made shipowners to look at other fuel types. Currently steam turbine accounts for about 70% of the fleet while diesel-electric (14%) and slow speed diesel engines (16%) are the lesser popular propulsion methods. When looking at the orderbook a rigorously different composition can be foreseen since diesel-electric account for 80% of the new ordered vessels while steam turbine and slow steam diesel engines both account for 10%. The advantage of diesel-electric over the steam engine is higher efficiency, more compact and it gives the shipowner more freedom in crewing. For larger vessels such as the Qflex and the Qmax vessels, slow speed diesel engines with a re-liquefaction plant are recommended (Clarksons, 2013).

Ice Class

The classification of a vessels capability to navigate through ice is referred to by the IMO as polar class but there are many different classifications and they are often referred to as ice class. In appendix 3 a conversion table can be found that translates the IMO Polar Classes to the Swedish-Finnish and other classifications. In general, vessels require a hull strengthening structures, special equipment that can operate in the cold, special building materials such as abrasion and corrosion resistant coatings, safety equipment, operation routines, etc. The guidelines set by the IMO (2010) cover general, construction, equipment, operational and environmental protection and damage control aspects. In the following table the allowable conditions for navigation in ice-covered waters, according to the IMO (2010) guidelines, are presented:

POLAR CLASS	GENERAL DESCRIPTION
PC 1	Year-round operation in all ice-covered waters
PC 2	Year-round operation in moderate multi-year ice conditions
PC 3	Year-round operation in second-year ice which may include multi-year ice inclusions
PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
PC 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

Table 8: Polar class general description. **Source: International Martime Organisation (2010)**

In July 2013 there were 29 ice class vessels in the fleet with five on order (Clarksons, 2013). A major order this year was made by the Total-Novatek joint venture to Daewoo Heavy Industries for the construction of the 16 PC-4 ice class carriers for the Yamal LNG project (Total, 2014b). The vessels are intended as shuttle tankers during the sailing season from May to December (Clarksons, 2013). They have an icebreaking stern and therefore do not require the escort of the Russian icebreakers (Total, 2014).

3.3.3 Current Trading Routes

Since trade is moving from each location of supply (red areas) to many different import hubs (green areas) it is difficult to identify typical trading routes. LNG is moving from everywhere to everywhere. However, it is obvious that East Asia generates the largest flows as importing regions and Qatar the largest as exporter. As a result the Suez Canal and Malacca Strait are primary transit points for LNG trade. Figure 9 gives a geographical overview of different supply hubs and importing regions as used in the model hereafter. Note, the size of the areas does not necessarily indicate higher volumes but are only chosen to represent a geographical area. The world has been divided in the following regions that are used in the model:

Origin (Supply)	
Alaska	0.07%
Algeria	3.60%
Australia	10.18%
Eastern Russia	4.13%
Egypt	1.99%
Hammerfest, Norway	1.26%
Malay Archipelago	22.39%
Arabian Peninsula	40.23%
Peru	1.35%
Trinidad	5.91%
West Africa	8.90%

Destination (Demand)	
Arabian Sea	7.55%
Argentina	1.27%
Brazil	1.86%
Chile	1.08%
China/Taiwan	23.86%
GoM, Carribean	3.23%
Japan	31.35%
Mediteranean	9.26%
Western Europe	4.58%
Northeast America	0.76%
South Korea	14.45%
Thailand	0.67%
Mexican Westcoast	0.09%

Tables 9 and 10: Supply and demand regions with share of traded volume (2012)

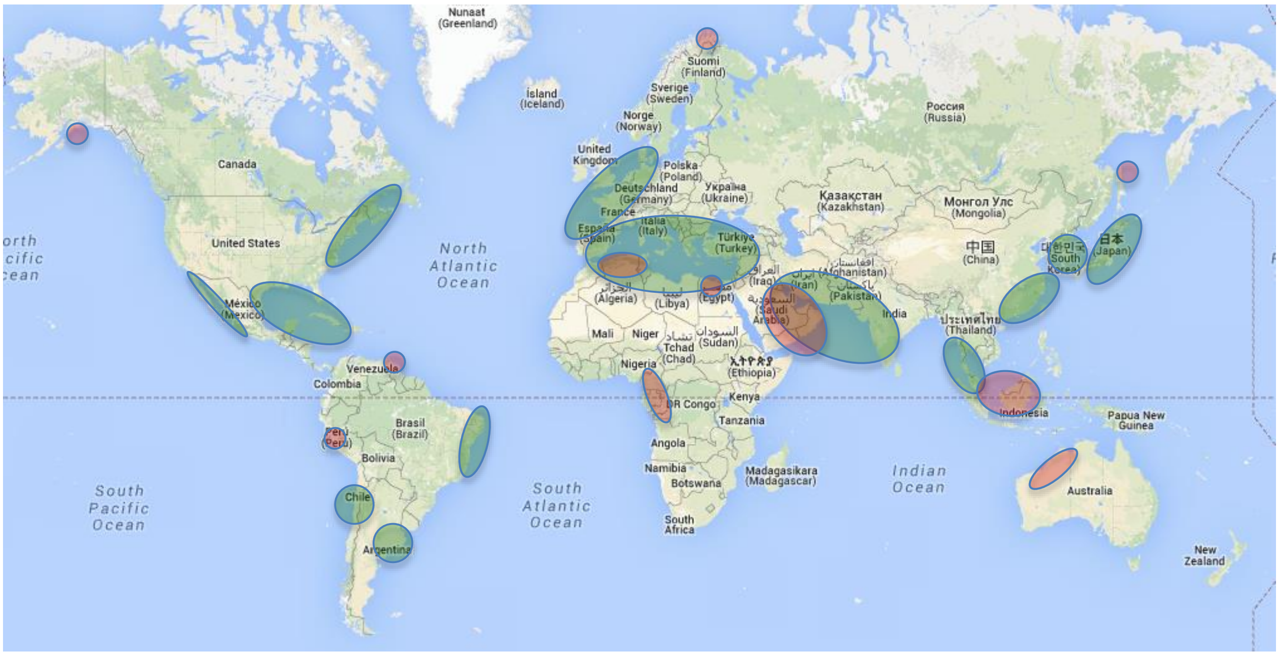


Figure 9: Supply (red) and Demand (green) Map

From these locations the following trade routes can be derived. The follwing routes are used in the model, which will be discussed in the next section.

- Direct/Regional Route
- Panama Canal
- Cape Hope
- Cape Horn
- Suez Canal
- Northern Sea Route
- Northwest Passage

4. Methodology

4.1 The GSIM Methodology

4.1.1 The Model

The Global Simulation (GSIM) Model has been developed by Francois and Hall (2002) and is designed to analyse changes in global trade policy. It is a partial equilibrium model, being industry based and excluding income effects. The model is built on the relative difference in the free-flow of trade linkages (origin-destination), represented by import tariff equivalents. These are represented in three input matrices: initial origin-destination trade flows that represent import demand, initial import tariff equivalents and final import tariff equivalents.

General assumptions are:

- Markets are clearing
- Imports are imperfect substitutes for each other
- Elasticities of supply, demand and substitution are held constant
- Fixed prices i.e. demand changes are solely driven by tariff changes

The assumption of imperfect substitutes is questionable since LNG is a very homogeneous product. On the other hand, countries and companies are from a strategic perspective generally inclined to diversify their energy supply. Therefore, even though the product and its quality are very homogeneous (95%-98% methane gas), imports do not have to be perfect substitutes. This assumption is supported by the data that shows that countries import LNG from often many different regions, regardless if supply is available in large amounts (and presumably at competitive prices) closer located to the destination port. This discrepancy might also be explained by (non)tariff trade barriers other than transport cost such as language and cultural differences, bureaucracy, risks, regulations etcetera.
When looking at the third and fourth assumption, one has to realise that the navigability of Arctic shipping develops over an extended period of time rather than over night or the chick of a button.

The application of this model to this problem is chosen because it enables identification of deviations and changes in the relative size of trade flows and the use of shipping routes as a result of a (partial) removal of the trade barrier for transarctic trade relations. Appendix 6 contains a summary of the mathematical foundation for the GSIM methodology.

This research assumes a market situation in 2040 based on current trade data, which is adjusted according to demand, export capacity and import capacity estimates at current prices. Prices in 2040 however are unlikely to be the same levels as 2012. It is beyond the scope of this research to forecast the 2040 market situation as it is focussed solely on the (relative) impact of open Arctic shipping routes.

Indexes	
$\boldsymbol{r},\boldsymbol{s}$	Origin points
$\boldsymbol{v},\boldsymbol{w}$	Destination points

Table 11: Notation Indexes GSIM. **Source: Van Elswijk (2012)**

Parameters	
$\boldsymbol{Es}$	Elasticity of substitution
$\boldsymbol{Em(v)}$	Import demand elasticity
$\boldsymbol{Ex(r)}$	Elasticity of export supply

Table 12: Notation Parameters GSIM. **Source: Van Elswijk (2012)**

Calibrated coefficients	
$\boldsymbol{N(v)(r,r)}$	Own price demand elasticity
$\boldsymbol{N(v)(r,s)}$	Cross-price elasticity
$\boldsymbol{T(v),r}$	The power of the trade barrier, T=(1+t)
$\boldsymbol{\theta(v),r}$	Demand expenditure share
$\boldsymbol{\varphi(v),r}$	Export quantity share

Table 13: Notation Calibrated coefficients GSIM. **Source: Van Elswijk (2012)**

Variables	
$\boldsymbol{M}$	Imports (quantity) by demanding regions
$\boldsymbol{X}$	Flow of LNG to demanding markets (quantity)
$\boldsymbol{P}$	Composite domestic price
$\boldsymbol{P^*(r)}$	World price for LNG leaving r
$\boldsymbol{P(r),v}$	Internal prices from origin/route r destined for destination v
$\boldsymbol{t(r),v}$	Barrier to trade (tariff equivalent) from r to v.

Table 14: Notation Variables GSIM. **Source: Van Elswijk (2012)**

Calibration of coefficients in the model is done through the following formulas (Van Elswijk, 2012):

(1) $\theta(\mathrm{i,v}),\mathrm{r} = \frac{\mathrm{M}(v),r\ \mathrm{T}(v),r}{\Sigma \mathrm{M}(v),s\ \mathrm{T(i,v)},s}$

(2) $\varphi(\mathrm{i,v}),\mathrm{r} = \frac{\mathrm{M}(i,v),r}{\Sigma \mathrm{M}(i,w),r}$

(3) $\mathrm{N}(i,v)(r,s) =]\theta(i,v),s\ (\mathrm{E}m + \mathrm{E}s)$

(4)
$\mathrm{N}(i,v)(r,r) = \theta(\mathrm{i,v}),\mathrm{r\ Em} - \Sigma_{sr}\theta(i,v),s\ \mathrm{E}s = \theta(i,v),r\ \mathrm{E}m - (1-\theta(i,v),r)\mathrm{E}s$

(5) Market clearing condition: $\widehat{X}_{i,r} = \widehat{M}_{i,r}$

$$E_{X(i,r)}\hat{P}^* = \sum_v N_{(i,v),(r,r)}\hat{P}_{(i,v),r} + \sum_v \sum_{s\,r} N_{(i,v),(r,s)}\,\hat{P}_{(i,v),s}$$
$$= \sum_v N_{(i,v),(r,r)}[P_r^* + \hat{T}_{(i,\square),r}] + \sum_v \sum_{s\,r} N_{(i,v),(r,s)}\,[\hat{P}_s^* + \hat{T}_{(i,\square),s}]$$

4.1.2 Application to this Research

The model was initially built to analyse changes in bilateral trade but in this situation supply and demand is clustered in regions and in combination with the use of the maritime trade lanes, discussed in section 3.3.3, the impact on trade and shipping routes is analysed. Costs of maritime transport are expressed as a percentage of total trade value, which is the tariff equivalent.

The analysis of the scenarios is performed in two steps. First the impacts of the reductions in tariff equivalents per main and sub scenario are modelled in accordance with the GSIM methodology. Second, each trade flow will be split into seven sailing routes. Trade between Eastern Russia and the Arabian Sea region thus will be expressed in the following way:

E. Russia (Direct)	Arabian Sea
E. Russia (Panama)	Arabian Sea
E. Russia (Horn)	Arabian Sea
E. Russia (Hope)	Arabian Sea
E. Russia (Suez)	Arabian Sea
E. Russia (NSR)	Arabian Sea
E. Russia (NWP)	Arabian Sea

The lowest tariff equivalent will be assumed to be the determinant of the chosen shipping route (i.e. the most economical route will be used for every single trade). In the case where the Arctic routes are most economical, where generally no year-round navigation is possible, the weighted average of the Arctic route and the conventional routes is used in the GSIM runs after which the trade flows will be split based on days of navigability.

4.2 Scenarios

Two main, supply based, scenarios will be used that will be projected upon three navigability scenarios. One of the main scenarios assesses solely the climatological impact (C) and one, aggregated scenario (A), takes into account the new production and regasification facilities that have currently passed the FID or are in a (pre)FEED stadium. For the year 2040, three scenarios of navigability are made, the high navigability (HN), the low navigability (LN) and the most likely scenario (ML). This results in the following integrated scenarios:

- C-HN: Climatological, High Navigability Scenario
- C-LN: Climatological, Low Navigability Scenario
- C-ML: Climatological, Most Likely Navigability Scenario
- A-HN: Aggregated, High Navigability Scenario
- A-LN: Aggregated, Low Navigability Scenario
- A-ML: Aggregated, Most Likely Navigability Scenario

To put these results into perspective, two scenarios were added where zero ice (NI) is assumed. Although these scenarios are not feasible, they give a good indication of the upper boundary of Arctic shipping under current and aggregated LNG market conditions.

- C-NI: Climatological, No Ice Scenario
- A-NI: Aggregated, No Ice Scenario

One should be aware that the LNG trade is affected by seasonality. Especially on the northern hemisphere gas is used for heating, which boosts LNG demand in winter. At the same time the Arctic routes experience their lowest navigability season. Seasonal effects of the LNG market have been considered outside the scope of this research.

4.2.1 Climatological Scenarios

In the climatological scenarios current existing import and export locations are taken into account with 2012 traded volumes increased by the compounded annual growth rates up to 2040 from table 7. New production capacity and import capacity is not taken into account and hereby solely the effect of the retreating sea ice is analysed.

4.2.1 Aggregated Scenarios

The Aggregated Scenarios take into account the new projects that currently have passed the FID or are in a (pre)FEED stadium, taking into account the shift from the US as an importing to an exporting nation. This is particularly interesting since it, in comparison with the climatological scenarios, will show what the impact of Arctic LNG production and other new facilities will mean for (trans)arctic LNG shipping and how locations of supply and demand affect the results.

New liquefaction capacity

The most important developments in liquefaction capacity for the coming decade have been discussed in section 3.2.1. I total there are 16 projects (total capacity: 95 MTPA) under construction, 20 projects (total capacity: 168.9 MTPA) in the FEED stage and 44 projects (total capacity: 329.45 MTPA) proposed among which the Yamal project and several projects in the US (Clarksons, 2013). Also it is assumed that decommissioning of existing capacity will be either replaced at the same location, or taken over by new capacity in the region.

Newcomers to the liquefaction club are Columbia (only 0.5 MTPA), Papua New Guinea, United States (Gulf of Mexico and Oregon), Canada (primarily British Colombia), Mozambique, Israel, Cameroon, Cyprus and Tanzania.

2012/new capacity (mpta)				Post 2021 rank	
Region	2012	new		Region	Capacity (mpta)
Arabian Peninsula	101	3.2		Gulf of Mexico	189.45
Malay Archipelago	65	23.5		Australia	106.2
West Africa	26	48.6		Arabian Peninsula	104.2
Australia	23	83.2		Northwest America	95.6
Algeria	19	9.2		Malay Archipelago	88.5
Caribean	16	1		West Africa	74.6
East Mediteranean	12	13		Northeast America	45
Russia East	10	20		Russia Kara	32.5
Norway, Hammerfest	5			Russia East	30
Peru	4			Algeria	28.2
Northwest America	2	93.6		East Africa	26.6
East Africa		26.6		East Mediteranean	25
Gulf of Mexico		189.45		Caribean	17
Russia Kara		32.5		Norway, Hammerfest	5
Northeast America		45		Peru	4
Total	**283**	**588.85**			**871.85**

Table 15: Current and Future Liquefaction Capacity. **Data: Clarksons (2013)**

New regasification capacity

In the market for LNG imports are Poland, Ukraine, Lithuania, Jordan, Pakistan, Sri Lanka, Bangladesh, Benin, Estonia, Finland, Lebanon, Sweden, Uruguay, Vietnam, Bahrain, Croatia, Ireland, Kenya, Philippines, South Africa, Morocco and Latvia. The regions used in the climatological scenario are adjusted for new importers and exporters into the regions shown in tables 15 and 16. Figure 10 shows the map with new regions of capacity adopted for the aggregated scenario.

2012/new capacity (mpta)				Post 2021 rank	
Region	2012	new		Region	Capacity (mpta)
Japan	180	6		Japan	186
GoM, Carribean	130	-80		Mediteranean/Ukraine	140.5
South Korea	91	4.5		South Korea	95.5
Mediteranean/Ukraine)	73	67.5		Arabian Sea	79.8
Western Europe	59.5	19.6		Western Europe	79.1
China/Taiwan	32	26.2		China/Taiwan	58.2
Arabian Sea	20.5	59.3		GoM, Carribean	50
Northeast America	15	3		Bay of Bengal	38.4
Malay Archipelago/SEA	18.6	23.7		Malay Archipelago/SEA	42.3
Mexican Westcoast	13	9.8		Mexican Westcoast	22.8
Argentina/Uruguay	8	2.5		Northeast America	18
Brazil	6	5.9		Chile	12.9
Chile	4	8.9		Brazil	11.9
Baltic		8.4		Argentina/Uruguay	10.5
Bay of Bengal		38.4		Baltic	8.4
South/East Africa		4.5		South/East Africa	4.5
Total	**650.6**	**208.2**			**858.8**

Table 16: Current and Future Regasification Capacity. **Data: Clarksons (2013)**

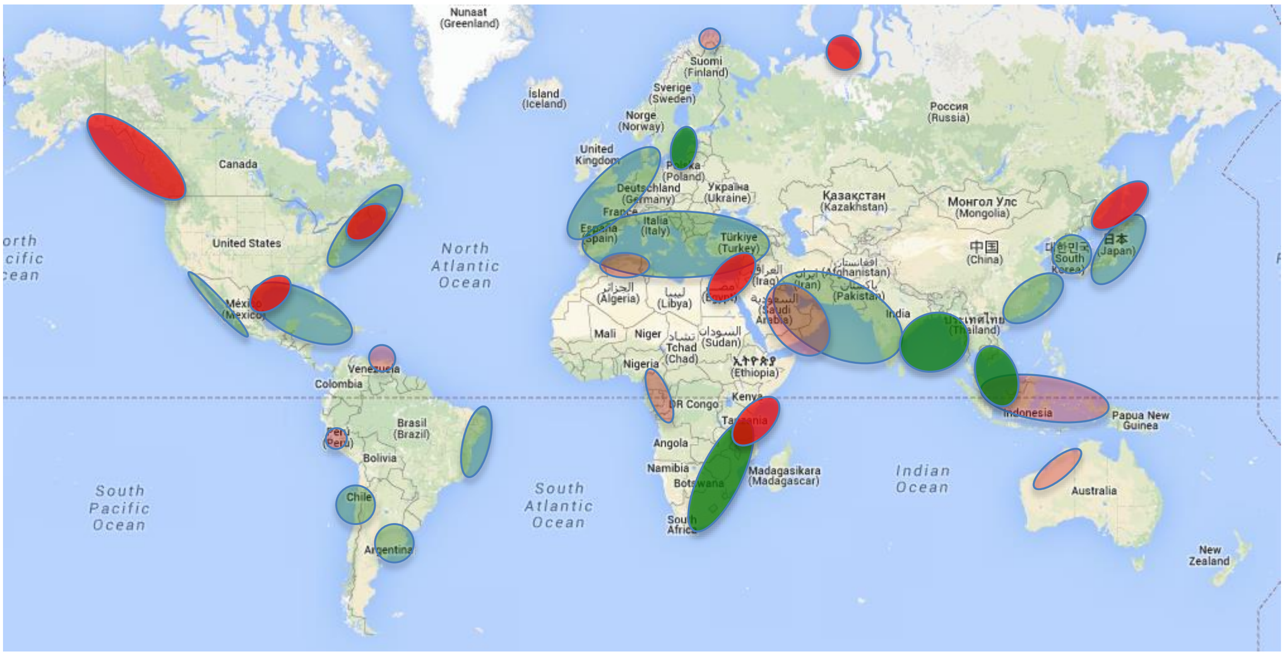


Figure 10: New (bright) Supply (red) and Demand (green) Map

Calibration into Trade Flows Usable for Model

New capacity is calibrated based on initial trade from the climatological scenario. For countries that already had existing figures on trade, demand was increased according to the growth of import capacity (i.e. per column). For the tree (Bay of Bengal, Baltic and South/East Africa) importing and exporting regions that had no initial existing trade flows were based on reasoning. The initial shares if import origins have been used as a starting point after which the new export capacity has been integrated.

In the initial situation US exports are not ranked as largest which might seem in contradiction to the liquefaction capacity. However, the vast majority of projects in the US have not passed the pre-FEED stage yet and it is unlikely that all would be executed. Therefore a downward correction has been made to account for this.

4.3 Initial Tariff Equivalents for Maritime LNG Trade

For the analysis, only the use of 155000 cbm fully laden, PC6 or OW, LNG carriers running on boil-off gas is assumed. The reason for this assumption is that multiple vessel sizes with different dimensional restrictions and economies of scale unmanageably complicate the analysis. This assumption is not unreasonable since the 155000 cbm LNG carrier is often referred to as the standard in terms of carrying capacity. Also empty legs are not separately taken into consideration. Since in the case of a shuttle service the empty leg is generally subsidised by the fully laden leg, the cost of the empty haul therefore considered to be incorporated in the freight rate.

4.3.1 Direct Cost Savings

The most important determinant of cost is the amount of sailing days. Aside from the charter rate, the trader is exposed to fuel cost and inventory holding costs. Boil-off costs is assumed to be incorporated in the fuel cost since the boil-off gas either acts as a fuel or is re-liquefied by fuel consuming cooling units.

Charter rate

As a charter rate for regular, open water, LNG carriers with a cargo capacity of 155,000 cbm the average spot charter rate of $122,000 from August to November 2012 (RS Platou, 2012; Haeffelé, 2013) is used.

The charter rates for polar class or regular open water vessels differ of course. Although both prices are determined by the market and are not likely to behave the same with only proportional differences, it is difficult to assess polar class charter rates individually since there is not yet a clear developed market existing. Therefore in the analysis the difference in CAPEX and OPEX between open water and PC-6 vessels (discussed in the next section) is used to make an estimate of the PC-6 LNG Carrier charter rate.

4.3.2 Capital, Operating and Voyage Cost

Capital costs

To compare the investment capital cost of a PC6 and a regular open water carrier with both 155.000 cbm cargo capacity three neworder vessels were compared.

Yard or owner	Ice class	Capacity	Price	Source
Dynagas (on order 2013)	1A S (PC6)	155 000 cbm	$235 m	(Clarksons, 2013) (Howard, 2014)
Newbuid price 2013	No	150 000 cbm	$185 m	(Clarksons, 2013)
Newbuid price 2013	No	160 000 cbm	$200 m	(Clarksons, 2013)

Table 17: LNG Carrier Newbuild Prices (2013)

$$\frac{235}{(\frac{185+200}{2})} = 1.22 = building\ cost\ ratio\,\frac{PC6}{OW}$$

It is a very simplistic approach and should be interpreted with care since capital cost for vessels can vary drastically (Stopford, 2009). However, due to availability of information and the scope of this research, PC6 vessels are assumed to be 22% more expensive than regular open water LNG carriers. This does not differ much from the assumption of 30% higher building cost DNV (2010) used for assessing the feasibility of the NSR for 6500 TEU PC4 container vessels.

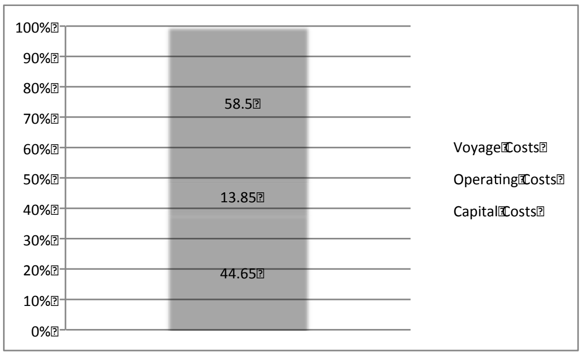


Figure 11: Cost Structure LNG Shipping. **Data: Petroleum-Economist (2011)**

It is assumed that the complete difference in cost is translated into the charter rate (i.e. profit margins for the shipowner are assumed to be equal for PC6 and OW vessels). Given the distribution of costs in figure 11, the charterer of a PC6 LNG carrier pays a charter rate of 22%*44.65% = 9.832% more caused by a higher building cost. This translates into a contribution to the charter rate of $11995.

For the oil/gas industry (sub: integrated) a WACC of 7.71% is assumed based on the estimates consolidated by NYU Stern (2014).

The daily inventory cost for the cargo at sea is therefore: (LNG trading price)*618/365

$$LNG\ Trading\ Price * Trading\ Volume * \frac{0.0771}{365} =$$

$$Traded\ Value * 0.021\% = \textit{Daily cost of inventory at sea}$$

Operating costs

DNV (2010) assumed 50% higher operating cost for 6500 TEU PC4 and for double acting (i.e. icebreaking stern) vessels compared to open-water vessels with the same cargo capacity. Since DNV (2010) considered no difference in operating costs between different ice class vessels and only differences in capital costs (120%

higher for double acting PC2 compared to 30% for PC4), this assumption is adopted and a 50% higher operating cost for PC6 LNG carriers is considered over open-water LNG carriers.

Just as in the case for capital costs, the 50% higher operating cost is assumed to be fully absorbed into the charter rate resulting in a 50%*13.85% = 6.925% increase. This translates into a contribution to the charter rate of $8449.

Voyage costs

The most important part (counting for approximately 66%) of voyage cost is fuel consumption (Stopford, 2009). The following table shows the fuel consumption at different sailing speeds for a 150.000 cbm LNG carrier that runs on boil-off gasses. At low speeds the vessel consumes less fuel than boils off and loses cargo. Especially when this happens for longer periods. Therefore sailing speeds should be around 12.5 knots minimum (Haefellé, 2013).

Speed (knots)	boil off fuel/day (tons)
19	104.05
18	93.12
17	84.62
16	76.92
15	69.23
14	63.97
13	58.70
12	54.66

Table 18: Fuel Consumption of a 150.000 cbm LNG carrier. **Data: Haefellé (2013)**

Vessels transiting the Panama and Suez Canal burn less fuel due to slower speeds and waiting times. These savings are assumed to be offset by cargo loss due to boil-off. On the Arctic routes the vessels require an extra consumption of 4 tons of LNG per day for the winterization of the vessel (Haefellé, 2013).

It is very likely that technologies improve over the coming 28 years that will decrease the consumption of fuel and thereby reduces the importance of sailing distance. In this research, a possible increase in fuel efficiency is ignored since it is unclear how these benefits will be distributed over regular or PC vessels. Also the aim of this research is to assess the impact of open Arctic shipping routes (i.e. shorter sailing distances), if based on loose assumptions the importance of distance will be decreased it will be more difficult to identify the impacts of Arctic routes.
For the routes facing a piracy thread and for the Arctic routes, insurance premiums need to be taken in to account that are not yet integrated in the aforementioned charter rate. For the routes crossing the grey shaded areas in figure 12 this includes extra insurance for the crew and war risk to cope with the thread of piracy. These insurance costs can, in comparison, be neglected for other shipping routes (US Maritime Administration, 2008).

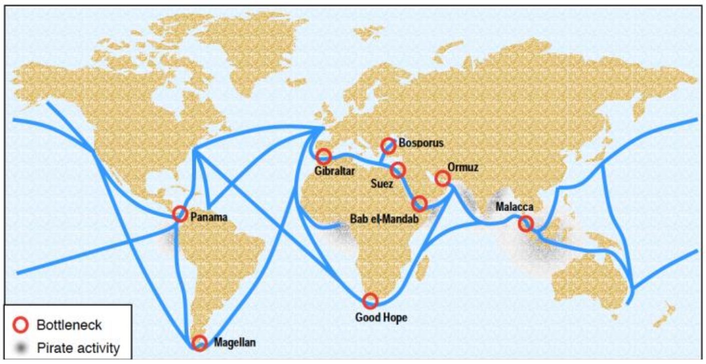


Figure 12: Piracy Activity Map. Source: OECD (2003)

According to Haeffelé (2013) the cost of insurance for a 155.000 cbm LNG carrier when transiting the Suez Canal is approximately $65,000. In this research this insurance premium is assumed for all routes navigating through piracy risk areas. The insurance cost of transiting the NSR for the Ob River in 2012 was $160,000 for a fully laden transit (Haeffelé, 2013), i.e. $17778 per day. The same daily premium is assumed for the NWP. The premium is mainly driven by higher pollution risk and hull and machinery damages.

4.3.3 Transit Dues

An LNG carrier with a cargo capacity of 155.000 cbm has a gross tonnage of approximately 100100 metric tons. For the chosen vessel size the following transit dues are calculated:

Transit	Fee/ton	Tons cargo	total fee
Suez Canal		62753	$554,732.60
Panama Canal	4.68/ton	62753	$345,825.64
Northwest Passage	50265/day	62753	$359,037.87
Northern Sea Route	$40739/day + $15000	62753	$381,648.00

Table 19: Transit Dues. **Data: Haeffelé (2013), Canal de Panama (2012), Eger (2010)**

The NSR fee is based on the fee that the Ob River paid in 2012 and includes pilotage cost of 2*$600/day (Haeffelé, 2013) and commercial agency costs of $15000 (Haeffelé, 2013). As there is no fee system for the NWP, the icebreaker cost of $50,000 per day according to the Canadian Coast Guard is assumed as the transit fee (Eger, 2010) plus $265 per day for a pilot (Somanathan, 2007). The Suez Canal dues include expenses for pilotage, tugs, mooring etc. (Bimco, 2014), the same costs are assumed for the Panama Canal.

4.3.4 Ice Restrictions and Annual Navigability

Looking back at section 2.2 where Smith and Stephenson (2013) assessed technically feasible transits the feasibility of the OW transit in the period 2006 – 2015 for both RCP (+4.5 and +8.5) for the month September highly resembles the route the Ob River made in November 2012 and the Arctic Aurora made in September 2013. Following this observation the probability of a technically feasible transit provided by Smith and Stephenson (2013) of 61%-71% (66% average) for OW vessels on the NSR will be adopted as the actual probability of feasibility for PC6 class vessels including all relevant factors.

The first PC6 vessel entering the NSR in 2012 was made on the 23th of July while the last was the Ob River, leaving the NSR on the 18th of November (NSR Information Office, 2014). Therefore, at 2012 ice levels, 139 navigable days for a PC6 vessel are assumed. The tariff equivalent of a particular trade using an Arctic route is based the weighted average of navigable sailing days per year and the probability of a feasible transit.

$$P(T|AR)\frac{N}{365} = \ ANF$$

$$66\%\frac{139}{365} = \ 0.2513$$

Where P(T|AR) is the probability of a feasible transit over the Arctic routes (blue lines in figure 2) during the navigable season and N is the amount of navigable days per year.

If the tariff equivalent for the Arctic route, regardless of navigability, is smaller than the conventional routes, the Arctic routes is assumed to be used when navigable. The distribution of total traded value is estimated based on the navigability factor where ANF times the total traded values (during the navigable season) is shipped over the Arctic route and the remaining (1-ANF) is shipped over the conventional route during the rest of the year.

4.3.5 Conclusion

In the following table a summary of the costs from which the tariff equivalents can be derived is presented.

Vessel	cost driver	Direct/Regional Route	Panama Canal	Cape Hope	Cape Horn	Suez Canal	Northern Sea Route	Northwest Passage
OW	Cargo Capacity cbm	155000	155000	15500	155000	155000	-	-
	Cargo Capacity (m.t.)	62753	62753	6275	62753	62753	-	-
	Daily Charter Rate	$122,000	$122,000	$122,000	$122,000	$122,000	-	-
	Charter cost	1.994$S_{a,b}V_{a,b}$	1.994$S_{a,b}V_{a,b}$	1.994$S_{a,b}V_{a,b}$	1.994$S_{a,b}V_{a,b}$	1.994$S_{a,b}V_{a,b}$	-	-
	Insurance premium	$65000 D_p	$65000 D_p	$65000 D_p	$65000 D_p	$65000 D_p	-	-
	Fuel Cost	104.05*$S_{a,b}$	104.05*$S_{a,b}$	104.05*$S_{a,b}$	104.05*$S_{a,b}$	104.05*$S_{a,b}$	-	-
	Transit dues	-	$345,825.64	-	-	$554,732.60	-	-
	Cargo inventory cost	0.021%$S_{a,b}V_{a,b}P_b$	0.021%$S_{a,b}V_{a,b}P_b$	0.021%$S_{a,b}V_{a,b}P_b$	0.021%$S_{a,b}V_{a,b}P_b$	0.021%$S_{a,b}V_{a,b}P_b$	-	-
PC6	Cargo Capacity cbm	-	-	-	-	-	155000	155000
	Cargo Capacity (m.t.)	-	-	-	-	-	62753	62753
	Daily Charter rate	-	-	-	-	-	$143,000	$143,000
	Charter Cost	-	-	-	-	-	2.28$S_{a,b}V_{a,b}$	2.28$S_{a,b}V_{a,b}$
	Insurance premium	-	-	-	-	-	$17778/day	$17779/day
	Winterisation	-	-	-	-	-	4S_A$	4S_A$
	Fuel Cost	-	-	-	-	-	104.05*Sa,b+56.68*S_A	104.05*Sa,b+56.68*S_A
	Transit dues	-	-	-	-	-	$40739*$S_A$ + $15000	50265*S_A
	Cargo inventory cost	-	-	-	-	-	0.021%*$S_{a,b}V_{a,b}P_b$	0.021%*$S_{a,b}V_{a,b}P_b$

Table 20: Summary of LNG Shipping Costs

Taking the shipping costs as a proportion of total trade value for each trade relation over the feasible routes generates the values of tariff equivalents. The tariff equivalent for trade relation (a;b) over route *i* is explained by the following formula:

$$T(a;b)|PAN = \frac{1.994S_{a,b}V_{a,b}+S_{a,b}F_oP_b+0.00021S_{a,b}V_{a,b}P_b+65000D_p+T_{PC}}{V_{a,b}P_b} +1$$

$$T(a;b)|PAN = \frac{S_{a,b}(125129.48+117.28P_b)+65000D_p+T_{PC}}{62753P_b} +1$$

$S_{a,b}$ = Sailing days between a and b

$V_{a,b}$ = Shipped volume in tons between a and b (62753 tons since a fully laden 155000 cbm LNG carrier is assumed)

P_b = $ Price of LNG per ton in destination b

D_p = Dummy variable for piracy risk (1 if yes; 0 if no)

T_i = Transit dues for route i

F_o = Fuel consumption per day in open water (104.05 tons of LNG at 19 knots)

For Arctic routes the tariff equivalents are calculated according to the following formulas:

$$T(a;b)|NSR = \frac{S_{a,b}V_{a,b}(2.28+0.00021P_b)+S_A(17778+40739)+P_b((S_{a,b}-S_A)F_O+S_AF_A)+15000}{V_{a,b}P_b} + 1$$

$$T(a;b)|NSR = \frac{S_{a,b}(143076.84+117.23P_b)+S_A(58517-43.37P_b)+15000}{62753P_b} + 1$$

$$T(a;b)|NWP = \frac{S_{a,b}(143076.84+117.23P_b)+S_A(68043-43.37P_b)+15000}{62753P_b} + 1$$

S_A = Sailing days in Arctic ice covered waters
F_A = Fuel consumption per day in the Arctic (60.68 tons of LNG at 12.5 knots)

In the initial situation however, shipping on both the NSR and the NWP is assumed to be completely restricted by the ice and the lacking of a supporting ice class fleet and Arctic infrastructure. Although shipments have taken place, these are considered to be trial journeys. The routes are currently not widely accepted as an alternative for the conventional routes, which indicates another nontariff barrier for transatlantic maritime LNG trade, which is industry perspective. In the initial situation the tariff equivalents are set at 5 meaning that shipping on the Arctic routes is in no case preferred over. Also for other routes where it simply makes no sense to use (for example Algeria to Europe through the Suez Canal) a tariff equivalent of 5 is marked down.

In the scenarios of navigability the industry perspective is not considered to be of any restrictive influence anymore and therefore left out.

4.4 2040 Tariff Equivalents for Maritime LNG Trade

4.4.1 Competitive Pricing Panama and Suez Canal

When the Arctic routes are becoming more economically attractive due to retreating sea ice, they become viable competitors to the Suez and the Panama Canal. More intensive use of the Arctic routes will therefore most likely put pressure on transit dues for the Suez and Panama Canal. Pricing strategies of the Suez, Panama, NSR and NWP is a research on itself and is considered outside the scope of this research.

4.4.2 Assumptions

Infrastructure and Regulatory Framework

With respect to the state of Arctic infrastructure it can be assumed that, based on the research in section 2.5.3, that infrastructure in the Canadian Archipelago most likely will not be developed to an extend comparable to the NSR. Although the first cargo has been transited the Passage, this route is significantly more difficult to navigate and therefore costly than the NSR. The NWP is much more subject to sea ice and the future potential of the NWP as an economically viable shipping route is still questionable. Also, according to DNV (2010), the NWP is not accessible for large vessels. Together with low current investments, the infrastructure on this side of the Arctic is assumed to develop slowly over the coming decades.

The Northern Sea Route on the other hand has been developed extensively over the last decade and is considered as a very potential shipping route (see section 2.4.3). The Russian Federation has made the NSR one of its priorities and competitions around sovereignty seems to speed up investments. More importantly, the exploitation of natural resources is an important driver of NSR infrastructure development. The route is currently already being used as a transit route and a strong increase in cargo volumes is expected. The recent investment in a new generation of icebreakers is another indicator of Russia’s commitment to develop the Russian Arctic region. Also a clear framework of institutions exists that manage the development and governance of the NSR (see section 2.4.4). Considering that the infrastructure along the NSR is currently considered to be 10 years away from it’s required level (Vukmanovic and Koranyi, 2013) we can assume that infrastructure along the NSR in 2040 will not be a restrictive factor any more.

Shipping Supply

Shipowners are opportunists and therefore the supply of ice-class shipping capacity is assumed not to be a restrictive factor since capacity will grow when there is demand for transarctic shipping. Freight rates are a result of demand and supply in the shipping market, resulting from trade rather than the other way around. Therefore freight rates are assumed to be constant.

4.4.3 Navigability Scenarios

As a basis for the navigability scenarios the +4.5 and +8.5RCP ice forecast with corresponding navigability probability estimates for PC6 vessels by Smith and Stephenson (2013) are used in combination with DNV (2010) estimates of navigable days. The probability of a feasible transit over the routes presented by Smith and Stephenson for OW vessels increase from 64% to 96% for +4.5 RCP and 71% to 98% for +8.5 RCP. DNV (2010) estimated between 100 and 120 unassisted navigable days over route 3 (figure 3) for a PC4 vessel in 2030 and 2050 respectively. Be aware that this analysis uses strict route distances for the Northern Sea Routes but in reality vessels are likely to gradually move away from the pole as sea ice starts to grow and vice versa.

In the case of the NWP, tariff equivalents are assumed to be only dependent on navigable days as distance; sailing speed and transit dues do not change. The reason for this rather simplistic approach is that climatological conditions for the NWP are not considered to change to an extend that it will have impacts on the cost per transit but rather on the amount of feasible sailing days (and transits) per year. For costs to be reduced, conditions will have to improve to the extend where there is no requirement for icebreaker guidance, ice class and winterisation of vessels and sailing speed restrictions. Even in the most favourable scenario do these expenses exist for the NWP and is year round navigation not feasible.

High Navigability Scenario

Using the +8.5 RCP forecast with the PC6 (red) routes form Smith and Stephenson the transpolar becomes feasible. Infrastructure in the Canadian Arctic, as well as sufficient availability of Russian icebreakers at the North Pole is expected. In the HN scenario a PC6 vessel is assumed to be able to navigate unassisted for 70 days in 2040 and year round under assistance of an icebreaker directly across the North Pole (Transpolar Passage) with a probability of a feasible transit of 100%. On the NWP an average sailing speed of 12.5 knots and is navigable 250 days under icebreaking assistance. For the transpolar route an estimated average speed of 12.5 knots is assumed.

$$T(a;b)|TPP = \frac{S_{a,b}(143076.84 + 117.23P_b) + 318P_b + 513960}{62753P_b}$$

The tariff equivalent for the NSR for this scenario is a bit more complex. A major driver of the reduction in the tariff equivalent for the NSR is the shorter sailing distance. The route directly across the North Pole, also referred as the Transpolar Sea Route or the Transpolar Passage (TPP), is 700 nm shorter than the coastal NSR undertaken by the Ob River in 2012 (Ostreng et. al., 2013). The total distance of the route is therefore 700nm shorter with an Arctic route of 2700-700 = 2000 nm, which results in 6.67 days of sailing on the TPP.

Given that this route does not navigate through Russian national waters the fixed commercial service fee ($15000) payable at the NSRA will not be applicable anymore. However, since Rosatomflot is likely to offer icebreaking services in these waters the daily icebreaking plus pilotage fee of $40739 is taken into account.

Transits through the outer bounds of the NSR are for 98% percent likely to be feasible for OW vessels in September (Smith and Stephenson, 2013). Under the assumption that year round navigation is possible for vessels with a lower ice class than PC6, the tariff equivalent for this route is generated. For lighter ice class vessels the same capital and operating cost as OW vessels, 12.5 knots sailing speed, the same transit dues as initial NSR dues and the same insurance premium is assumed. The following three tariff equivalents are considered to generate a consolidated tariff.

- Transpolar route for a PC6 vessel during 70 day unassisted navigability; In this case the transit tolls and icebreaking fees have been subtracted.

$$T(a;b)|TPP = \frac{S_{a,b}(143076.84 + 117.23P_b) + S_A(58517 - 43.37P_b)}{62753P_b} + 1$$

- Transpolar route for a PC6 vessel during the residual 295 days where it needs icebreaker assistance over the route.

$$T(a;b)|TPP = \frac{S_{a,b}(143076.84 + 117.23P_b) + S_A(17778 - 43.37P_b)}{62753P_b} + 1$$

- Coastal NSR for an OW vessel without icebreakers but with the fixed transit toll of $15000 and $1200/day for two pilots.

$$T(a;b)|NSR = \frac{S_{a,b}(125129.48+117.23P_b)+S_A(58517-43.37P_b)+15000}{62753P_b} + 1$$

During the 70 days of unassisted navigability all traffic is assumed to take place over the transpolar passage and for the residual days the choice of route depend on which has the lowest tariff equivalent. The PC6 icebreaking route will be chosen if:

$$\frac{S_{(a,b|TPP)}(143076.84 + 117.23P_b) + S_{(A|TPP)}(17778 - 43.37P_b)}{62753P_b}$$

$$<$$

$$\frac{S_{(a,b|NSR)}(125129.48 + 117.23P_b) + S_{(A|NSR)}(58517 - 43.37P_b) + 15000}{62753P_b}$$

Solving for the average LNG price of $524 gives S(a,b|TPP) < 2.41 S(a,b|NSR) + 3.71 which is always true since S(a,b|TPP) < S(a,b|NSR). Therefore the Transpolar Passage (TPP) with icebreaking assistance will always be preferred over the coastal route. This enables us to generate one consolidated tariff equivalent based on the weighted average of both PC6 tariff equivalents:

$$\frac{70}{365}\frac{S_{a,b}(143076.84+117.23P_b)+S_A(17778-43.37P_b)}{62753P_b}+\frac{295}{365}\frac{S_{a,b}(143076.84+117.23P_b)+S_A(58517-43.37P_b)}{62753P_b}+1=$$

$$T(a;b)|TPP=\frac{S_{a,b}(143076.84+13.178P_b)+338196}{62753P_b}+1$$

Low Navigability Scenario

Using the +4.5 RCP forecast with the OW (blue) routes form Smith and Stephenson a shorter Northern Sea Routes become available (comparable to DNV route 3). For the LN scenario only 200 assisted sailing days over route 3 are assumed at 96% probability of a feasible transit. Infrastructure for the Canadian Arctic is expected to be underdeveloped while icebreaking services Russia are expected to be sufficient to support traffic. For the NWP therefore only 140 assisted sailing days are assumed. The average sailing speed on route 3 as well as the NWP is assumed to be 12.5 knots.

For the NSR, navigation happens almost entirely outside Russian national waters. Therefore the formula excluding tolls, as discussed in the high navigability scenario, is applicable. Major differences in this situation are in the ANF and the sailing distance. Arctic sailing distance is approximately 2000 nm, which is 400 miles shorter than the initial coastal route and takes approximately 7.67 sailing days in the Arctic.

$$ANF(NSR)=\ 96\%\frac{200}{365}=\ 0.526$$

$$T(a;b)|NSR=\ \frac{S_{a,b}(143076.84+117.23P_b)+332.65P_b+448825}{62753P_b}+1$$

If using the NSR is the most economical route there will be 0.526*365 = 192 days of sailing on the NSR and (1-0.526)*365 = 173 days of sailing on the conventional route annually.

For the NWP the same approach is taken:

$$ANF(NWP) = 98\% \frac{140}{365} = 0.376$$

$$T(a;b)|NWP = \frac{S_{a,b}(143076.84 + 117.23P_b) + 318P_b + 513960}{62753P_b} + 1$$

Leaving 137 navigable days on the NWP and 228 days on the conventional routes annually.

Most-Likely Navigability Scenario

As a basis for the most likely navigability scenarios the average of the +4.5RCP and +8.5RCP ice forecast with corresponding navigability probability estimates for OW vessels by Smith and Stephenson (2013) are used. DNV (2010) estimated between 100 and 120 unassisted navigable days over route 3 (figure 3) for a PC4 vessel in 2030 and 2050 respectively. This route correlates highly with the OW Northern Sea Routes from Smith and Stephenson (2013). Given the current attention to the arctic route from Russia the availability of icebreakers and other infrastructural requirements can be expected. PC6 vessels are assumed to be able to navigate unassisted for 100 days in 2040 and year round under assistance of an icebreaker, both with 98% probability of a feasible transit. With respect to the NWP only 250 assisted sailing days with a 98 probability of a feasible transit are estimated, primarily due to the harsher ice conditions in that region and the expectation that the infrastructure will only moderately be developed. Along both routes an average sailing speed of 12.5 knots is assumed.

$$ANF(NSR) = 98\% = 0.98$$

This leads to 358 navigable days on the NSR and 7 days of navigation annually over the conventional routes.

$$T(a;b)|NSR = \frac{S_{a,b}(143076.84 + 117.23P_b) + 332.65P_b + 363217.4}{62753P_b} + 1$$

$$ANF(NWP) = 98\% \frac{250}{365} = 0.671$$

Leaving 245 days of navigation on the NWP and during the remaining 120 days, the conventional route will be used.

$$T(a;b)|NWP = \frac{S_{a,b}(143076.84 + 117.23P_b) + 318P_b + 513960}{62753P_b} + 1$$

Zero Ice Scenarios

For the zero ice scenarios, year round navigation through the NWP and over the TPP is assumed with regular OW vessels and without the cost of icebreaker guidance and transit tolls.

$$\frac{S_{a,b}(125129.48 + 117.28P_b)}{62753P_b}$$

4.5 Data

4.5.1 Trade Data

Bilateral trade data (in volumes) for 2012, as well as the ports that accommodated these trades, has been obtained from the Clarksons (2013) report. These values have been multiplied by compounded regional growth rates to be fitted for the 2040 initial scenario (Clarksons, 2013). The trade in volumes has been converted to metric tons and from metric tons to dollar values based on data from the Federal Energy Regulatory Commission (2012).

The input trade data for the aggregated scenarios is calibrated as discussed in section 4.2.

4.5.2 Sailing Distance and Speed

Distances per sailing route have been determined by taking the average port-to-port distance, obtained from www.vesseldistance.com (2014), between the clustered supply and demand areas. The application gave the shortest and alternative routes including the NWP but excluding the NSR. The NSR distances between A and B were found by taking the distance from A to Hammerfest and B to Tobata for Asia bound shipments and B to Dutch Harbour for America bound shipments. These distances were then added to the Hammerfest-Tobata (or Hammerfest Dutch Harbour) distance distilled from the NSR Information Office (2014) statistics on NSR transits.

From the distances the sailing days were be calculated, based on the assumption of 19 knots sailing speed in open water and 12.5 knots in arctic waters which is based on the Ob River PC-6 transit over the NSR in 2012 (NSR Information Office, 2014). Delays for the Suez Canal were calculated based on information from the NGIA (2011) and delays for the Panama Canal were presented by ACP (2014).

Track		knots	nautical miles	transit time (days)
Suez Canal	Suez Canal/Bay	7.60	105	0.58
	Gulf of Suez	16	160	0.42
	Red Sea	16	1080	2.81
	waiting time			0.46
	average/total	13.15	1345	4.26
Panama Canal	Canal Transit incl. Waiting		50	1.02
Oceans and Seas	Open Water	19		
NWP	Baffin Bay - Beaufort Sea	12.5	2200	7.333333333
NSR	Kara Gate - Dezhnev Gate	12.5	2700	9
NSR Route 3	Kara Gate - Dezhnev Gate	12.5	2300	7.666666667
TPP		12.50	2000	6.666666667

Table 21: Transit Times. **Data: ACP (2014), NSR Information Office (2014), NGIA (2011), Ostreng et. al. (2013)**

4.5.3 Elasticities

The GSIM model requires three types of elasticities as input; Composite demand elasticity, industry supply elasticity and substitution elasticity. The elasticities of substitution are expressed as absolute numbers and elasticities of industry supply as positive numbers and are set on a value of 10 and 1.5 respectively for all destinations as done by Francis and Hall (2002).

For several regions (taking the average of available elasticities from countries within that region) elasticities of LNG import demand was available at the World Bank (2014). In cases were no estimates of LNG elasticities were available, elasticities of import demand for natural gas have been used. For a few regions elasticities were still not available through the World Bank database and estimates were made based on figures used by Baron et. al. (2013) and by own reasoning.

In the case for the US and Canada (regions: Northeast America and Gulf of Mexico only in the climatological scenarios) a current elasticity of import demand of -0.38 was estimated by Baron et. al. (2013). They forecasted, due to the increase in domestic production, a decrease in import elasticity to -0.53 in 2038. The elasticity of -0.38 and -0.53 is used for the climatological scenario and the aggregated scenario respectively.

The following elasticities have been used:

	Arabian Sea	Argentina	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Mediteranean	Western Europe	Northeast America	South Korea	Thailand	Mexican Westcoast
Composite Demand	-0.12	-0.12	-0.12	-0.43	-0.19	-0.20	-0.17	-0.51	-0.38	-0.38	-0.55	-0.45	-0.10
Industry Supply	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Substitution	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

Table 22: Elasticities used for the the Climatological Scenarios. **Data: World Bank (2014), Baron et. al. (2014)**

	Arabian Sea	Argentina/Uruguay	Baltic	Bay of Bengal	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Malay Archipelago/SEA	Mediteranean/Ukraine	Mexican Westcoast	Northeast America	South Korea	South/East Africa	Western Europe
Composite Demand	-0.42	-0.12	-0.77	-0.42	-0.12	-0.43	-0.19	-0.20	-0.17	-0.45	-0.51	-0.10	-0.53	-0.55	-0.25	-0.38
Industry Supply	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Substitution	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

Table 23: Elasticities used for the the Aggregated Scenarios. **Data: World Bank (2014), Baron et. al. (2014)**

5. Results

The results obtained through the GSIM analysis can be presented in several forms including percentage, share and value changes in route use, changes in (total or per route) values traded per importer and exporter, composite prices as well as absolute and relative impacts on consumer surplus, producer surplus and total welfare. In this section the results of the scenarios are presented in different forms and interpreted. Summarised results are presented to assess the relative impacts of navigability while here and there emphasis is put on the ‘most likely’ scenario results.

In the previous chapter the initial trade values, initial tariff equivalents and final tariff equivalents were estimated. In this chapter the impact of the reduced tariff equivalents (i.e. reduced barrier to trade due to sea ice and other factors) will be estimated through GSIM.

In section 5.1 the results of the Climatological scenarios are presented, in section 5.2 the results of the Aggregated scenarios are presented and in section 5.3 the two main scenarios are compared. In section 5.4 conclusions are made based on the three preceding sections.

5.1 Climatological Scenarios

The initial and post-GSIM trade values for the four navigability scenarios, together with the shares and percentage changes for exporters and importers are shown in table 24 and 25 respectively.

TOTAL VALUES						SHARES					PERCENT CHANGES			
EXPORTER	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN
Alaska	127	127	128	128	128	0.08%	0.08%	0.08%	0.08%	0.08%	-0.21%	-0.21%	-0.11%	-0.06%
Algeria	5799	5803	5785	5783	5781	3.60%	3.60%	3.59%	3.59%	3.59%	0.31%	0.38%	0.07%	0.04%
Australia	18923	18923	18938	18946	18954	11.75%	11.75%	11.76%	11.76%	11.77%	-0.17%	-0.17%	-0.09%	-0.04%
Eastern Russia	7801	7801	7807	7811	7815	4.84%	4.84%	4.85%	4.85%	4.85%	-0.18%	-0.18%	-0.10%	-0.05%
Egypt	3604	3604	3605	3605	3605	2.24%	2.24%	2.24%	2.24%	2.24%	-0.03%	-0.03%	-0.02%	-0.01%
Hammerfest, Norway	2158	2154	2129	2109	2088	1.34%	1.34%	1.32%	1.31%	1.30%	3.32%	3.15%	1.92%	0.99%
Malay Archipelago	23480	23480	23493	23499	23505	14.58%	14.58%	14.59%	14.59%	14.60%	-0.10%	-0.11%	-0.05%	-0.03%
Arabian Peninsula	71324	71324	71350	71364	71378	44.30%	44.30%	44.31%	44.32%	44.32%	-0.07%	-0.08%	-0.04%	-0.02%
Peru	2217	2217	2216	2216	2216	1.38%	1.38%	1.38%	1.38%	1.38%	0.04%	0.05%	0.02%	0.01%
Trinidad	9943	9942	9937	9933	9929	6.18%	6.17%	6.17%	6.17%	6.17%	0.14%	0.13%	0.08%	0.04%
West Africa	15637	15637	15640	15642	15644	9.71%	9.71%	9.71%	9.71%	9.71%	-0.05%	-0.04%	-0.03%	-0.01%
TOTAL	**161013**	**161012**	**161028**	**161035**	**161043**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**-0.02%**	**-0.02%**	**-0.01%**	**0.00%**

Table 24: Traded Values (million USD), Shares and Percent Changes per Exporter (Climatological)

TOTAL VALUES						SHARES					PERCENT CHANGES			
IMPORTER	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN
Arabian Sea	14164	14164	14163	14163	14162	8.80%	8.80%	8.80%	8.79%	8.79%	0.01%	0.01%	0.01%	0.00%
Argentina	2649	2649	2647	2646	2645	1.65%	1.64%	1.64%	1.64%	1.64%	0.14%	0.13%	0.08%	0.04%
Brazil	3872	3872	3871	3871	3870	2.40%	2.40%	2.40%	2.40%	2.40%	0.06%	0.05%	0.04%	0.02%
Chile	2202	2202	2201	2201	2201	1.37%	1.37%	1.37%	1.37%	1.37%	0.03%	0.03%	0.02%	0.01%
China/Taiwan	43113	43112	43120	43124	43127	26.78%	26.78%	26.78%	26.78%	26.78%	-0.03%	-0.03%	-0.02%	-0.01%
GoM, Carribean	4387	4387	4387	4386	4386	2.72%	2.72%	2.72%	2.72%	2.72%	0.01%	0.01%	0.01%	0.00%
Japan	41186	41187	41196	41202	41209	25.58%	25.58%	25.58%	25.59%	25.59%	-0.05%	-0.05%	-0.03%	-0.02%
Mediteranean	15040	15040	15039	15038	15037	9.34%	9.34%	9.34%	9.34%	9.34%	0.02%	0.02%	0.01%	0.01%
Western Europe	5113	5114	5114	5115	5115	3.18%	3.18%	3.18%	3.18%	3.18%	-0.03%	-0.03%	-0.01%	-0.01%
Northeast America	444	444	444	445	445	0.28%	0.28%	0.28%	0.28%	0.28%	-0.02%	-0.02%	-0.01%	-0.01%
South Korea	27445	27445	27447	27448	27449	17.05%	17.05%	17.04%	17.04%	17.04%	-0.01%	-0.01%	-0.01%	0.00%
Thailand	1207	1207	1207	1207	1207	0.75%	0.75%	0.75%	0.75%	0.75%	0.00%	0.00%	0.00%	0.00%
Mexican Westcoast	190	190	190	190	190	0.12%	0.12%	0.12%	0.12%	0.12%	-0.04%	-0.04%	-0.02%	-0.01%
TOTAL	**161013**	**161012**	**161028**	**161035**	**161043**	100.00%	100.00%	100.00%	100.00%	100.00%	-0.02%	-0.02%	-0.01%	0.00%

Table 25: Traded Values (million USD), Shares and Percent Changes per Importer (Climatological)

As shown in the figures above the impact in terms of total traded values is only marginal, a reduction of 0.01% for the Most Likely scenario and 0.02% if all the ice would disappear. The reduction in traded value is explained by a stronger negative effect on world prices than the positive effect on traded quantities. This theory is supported by the fact that net producer surplus decreases when the routes become more navigable (table 27). The strongest and only really significant change in total traded value is from Hammerfest, Norway (+1.92% in the ML scenario). The effect on its trading partners China, Japan and North Korea are as a percentage smaller; first, since the traded value originated from Norway is split into three destinations and second, Norway's initial total traded values is much smaller in relation to the traded values from the three aforementioned importing countries which leads to a larger proportional effect.

The following table gives more detailed insight in the changes in traded values. The most significant trade deviations are from Norway where an increase in traded value to Japan (+46.6%), South Korea (39.8%) and China/Taiwan (+24.3%) is observed. As shown in the table, trades to other trading partners of Norway decreased between 6.9% and 7.7%.

C-ML (%Δ Traded Value)	Arabian Sea	Argentina	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Mediteranean	Western Europe	Northeast America	South Korea	Thailand	Mexican Westcoast
Alaska	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Algeria	-0.3	0.0	0.0	0.0	-0.5	0.0	-0.8	0.1	-0.1	0.0	-0.5	0.0	0.0
Australia	0.3	0.0	0.0	0.0	0.1	0.0	-0.2	0.0	0.0	0.0	0.1	0.0	0.0
Eastern Russia	0.0	0.0	0.0	0.0	0.2	0.0	-0.1	0.0	0.0	0.0	0.2	0.0	0.0
Egypt	0.1	0.9	0.0	0.4	-0.2	0.3	-0.4	0.5	0.3	0.0	-0.1	0.0	0.0
Hammerfest, Norway	-7.7	-6.9	-7.2	-7.3	24.3	-7.4	46.4	-7.3	-7.4	0.0	39.8	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arabian Peninsula	0.1	1.0	0.6	0.5	-0.1	0.4	-0.4	0.6	0.4	0.3	-0.1	0.1	0.0
Peru	0.0	0.0	0.0	0.0	0.0	0.2	-0.6	0.3	0.0	0.0	0.0	-0.1	0.0
Trinidad	-0.3	0.5	0.1	0.0	-0.6	-0.1	-0.8	0.1	-0.1	-0.2	-0.5	-0.4	0.0
West Africa	0.1	0.0	0.6	0.4	-0.1	0.4	-0.4	0.5	0.3	0.0	-0.1	0.1	0.0

Table 26: Percent Changes in Trade Value per Trade Relation (Climatological)

MOST LIKELY

Importers	CS	Price	**Exporters**	PS	Price
Arabian Sea	0.30	-0.002%	Alaska	-0.06	-0.045%
Argentina	-2.27	0.081%	Algeria	1.63	0.028%
Brazil	-1.90	0.046%	Australia	-6.52	-0.034%
Chile	-0.85	0.036%	Eastern Russia	-3.02	-0.039%
China/Taiwan	10.78	-0.024%	Egypt	-0.28	-0.008%
GoM, Carribean	-1.25	0.026%	Hammerfest, Norway	16.09	0.766%
Japan	23.23	-0.053%	Malay Archipelago	-4.70	-0.020%
Mediteranean	-6.76	0.043%	Arabian Peninsula	-10.94	-0.015%
Western Europe	-1.35	0.024%	Peru	0.15	0.007%
Northeast America	-0.07	0.014%	Trinidad	3.20	0.032%
South Korea	6.90	-0.024%	West Africa	-1.61	-0.010%
Thailand	0.07	-0.005%			
Mexican Westcoast	0.04	-0.020%			
Total Consumer Surplus	26.87		Total Producer Surplus	-6.04	
NET WELFARE EFFECT					20.82

Table 27: Welfare Effects (million USD) and Price Changes for the C-ML scenario

For more accurate insight in the effect on importers and exporters one has to look at the welfare effects. A total net welfare effect of $20.82 million and comparing this to the other scenarios, no massive differences are observed. The No Ice scenario shows a total net welfare effect of $40.70 million, HN of $40.64 million and the LN of $10.66 million. This in relation to a total market of $161 billion can be interpreted as a negligible. Remarkable is that the net welfare effects of the HN and NI scenarios are very close indicating that the marginal welfare effect is diminishing with navigability.

A closer look at the individual actors (see table 27 and figures 14 and 15) show that Hammerfest is, as expected, the main gainer among the producers. Among the importers China/Taiwan, Japan and South Korea the countries that gain directly and the most from the opening of the Arctic routes, which is in line with expectations since this demand located relatively close to the Bering Strait. Since these are the only trades that benefit directly from the increased navigability and Norwegian exports are in relation to the total market very small, the total welfare effects are marginal.

The following figures emphasise the differences in absolute impacts on producer and consumer surpluses. One has to take into account that relatively these differ depending on the market share of the producer or consumer. The negative impact on the surplus of the Arabian Peninsula for example is approximately one third smaller than the positive impact on Norway. In terms of prices however, the positive price effect for Norway (+0.766%) is much stronger than the negative price effect on the Arabian Peninsula (-0.015%). The reason for this is that Norway is a small exporter (5 MPTA liquefaction capacity) in relation to the Arabian Peninsula (Qatar only already has a liquefaction capacity of 77 MPTA). A relation between Norway's positive and Arabian Peninsula's negative effect exist because the Arabian Peninsula is, together with Australia, one of the major suppliers for Asian gas markets.

Because trade from Norway deviated towards Japan, China/Taiwan and South Korea, supply to the other regions decreased causing an increase in consumer prices for the Mediterranean, Western Europe, Gulf of Mexico, Argentina, Brazil and Northeast Americas. This reduction in supply allows Algeria, Peru and Trinidad to enjoy higher prices leading to an increase in surplus for these countries.

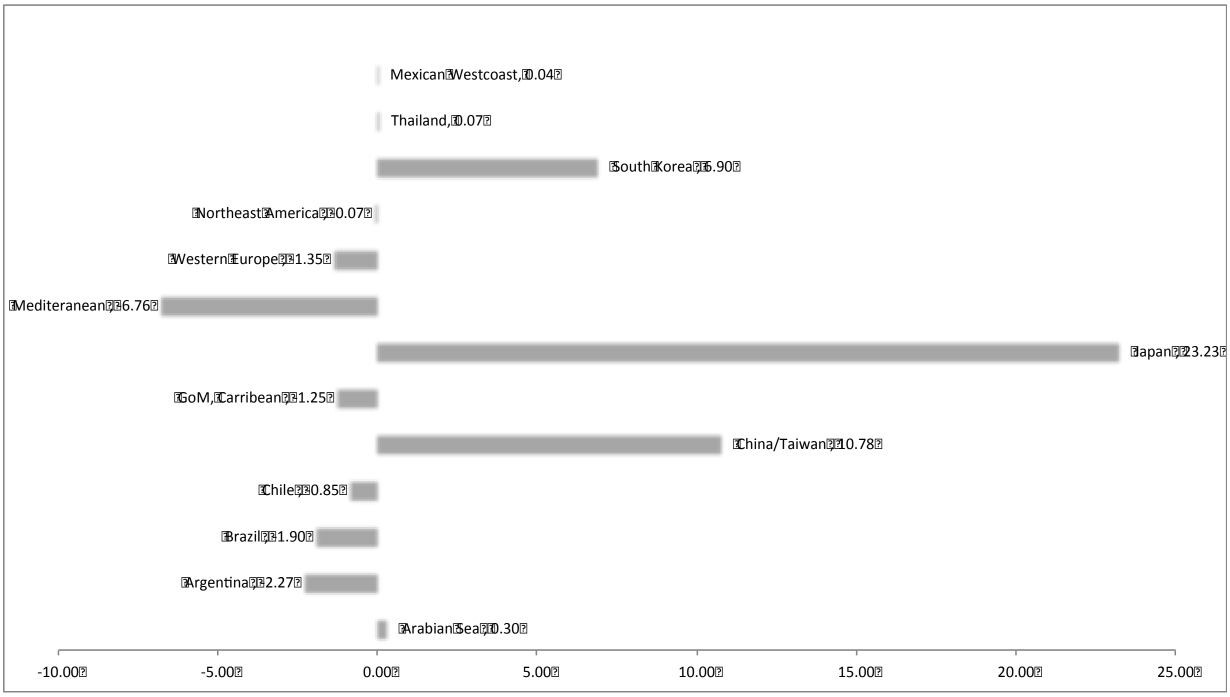


Figure 13: Consumer Surplus C-ML

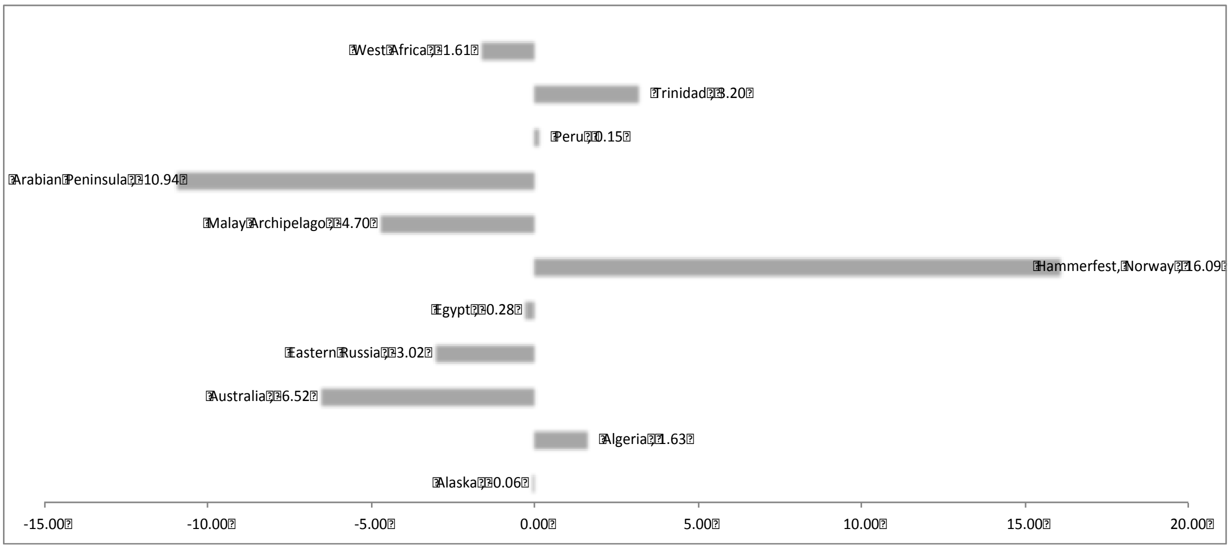


Figure 14: Producer Surplus C-ML

Tables 28 and 29 give an overview of the use of the NSR per importer and exporter for the different scenarios. In none of the cases is the NWP used and therefore a similar table for the NWP is left out.

NSR

EXPORTER	NI	HN	ML	LN	NI	HN	ML	LN
Alaska	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Algeria	373	0	0	0	37.36%	0.00%	0.00%	0.00%
Australia	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Eastern Russia	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Egypt	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Hammerfest, Norway	626	271	197	89	62.64%	100.00%	100.00%	100.00%
Malay Archipelago	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Arabian Peninsula	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Peru	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Trinidad	0	0	0	0	0.00%	0.00%	0.00%	0.00%
West Africa	0	0	0	0	0.00%	0.00%	0.00%	0.00%
TOTAL	**999**	**271**	**197**	**89**	100.00%	100.00%	100.00%	100.00%

Table 28: NSR Trade Flows (million USD) and Shares per Exporter (Climatological)

NSR

IMPORTER	NI	HN	ML	LN	NI	HN	ML	LN
Arabian Sea	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Argentina	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Brazil	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Chile	0	0	0	0	0.00%	0.00%	0.00%	0.00%
China/Taiwan	300	304	45	25	30.02%	30.34%	16.66%	27.91%
GoM, Carribean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Japan	578	574	193	53	57.82%	57.34%	71.31%	59.49%
Mediteranean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Western Europe	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Northeast America	0	0	0	0	0.00%	0.00%	0.00%	0.00%
South Korea	122	123	33	11	12.16%	12.32%	12.02%	12.60%
Thailand	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Mexican Westcoast	0	0	0	0	0.00%	0.00%	0.00%	0.00%

Table 29: NSR Trade Flows (million USD) and Shares per Importer (Climatological)

ROUTE	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN	INITIAL
Direct	129899	129896	130068	130152	130241	80.68%	80.67%	80.77%	80.82%	80.87%
Panama	4040	4041	4043	4045	4047	2.51%	2.51%	2.51%	2.51%	2.51%
Horn	13614	13613	13636	13645	13655	8.46%	8.45%	8.47%	8.47%	8.48%
Hope	337	337	336	335	335	0.21%	0.21%	0.21%	0.21%	0.21%
Suez	12123	12125	12674	12626	12765	7.53%	7.53%	7.87%	7.84%	7.93%
NSR	999	1001	271	232	[illegible]	0.62%	0.62%	0.17%	0.14%	0.00%
NWP	0	0	0	0	[illegible]	0.00%	0.00%	0.00%	0.00%	0.00%
TOTAL	**161013**	**161012**	**161028**	**161035**	**161043**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 30: Traded Values (million USD) and Shares per Shipping Route (Climatological)

Table 30 shows the total traded values and shares per sailing route. Although absolute values are small, over the different scenarios a significant effect in terms of route choice can be observed. Logically as the share of trade on the NSR increases decreases the share of Suez transits since Norwegian gas that initially went eastbound through the Suez Canal is now shipped on the NSR.

The small impact is attributable to the locations of supply and demand, established initial trade relations and the small share of the only favourable located supplier Norway. In the following table an overview is given, based on the tariff equivalents, when which route deviation is economical. As shown only sixteen of the current trade relations could benefit directly from increased navigability in the Arctic. Of these 16 relations, seven could benefit in the ML case of which only six (Norway – China/Taiwan, Japan, North Korea and Algeria – China/Taiwan, Japan, North Korea) had established trade flows in the initial situation.

ECONOMICAL SAILING DEVIATIONS (SUMMER ROUTES)

		NI		HN		ML		LN		CONV
Alaska	Mediteranean	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	NSR/PAN	192.A/173	NSR/PAN	PAN
	Western Europe	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	NSR/PAN	192.A/173	NSR/PAN	PAN
	Northeast Americas	365.U	NWP							PAN
Algeria	China/Taiwan	365.U	TPP							SUEZ
	Japan	365.U	TPP							SUEZ
	South Korea	365.U	TPP							SUEZ
Eastern Russia	Brazil	365.U	NWP	70.U/295.A	TTP					PAN
	Western Europe	365.U	TPP	70.U/295.A	TTP	100.U/265.A	NSR/SUEZ	192.A/173	NSR/SUEZ	SUEZ
	Mediteranean	365.U	TPP	70.U/295.A	TTP					SUEZ
	Northeast Americas	365.U	NWP	250.A/45.A/70.U	NWP/TPP					PAN
Hammerfest	China/Taiwan	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	NSR/SUEZ	192.A/173	NSR/SUEZ	SUEZ
	Japan	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	NSR/SUEZ	192.A/173	NSR/SUEZ	SUEZ
	South Korea	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	NSR/SUEZ	192.A/173	NSR/SUEZ	SUEZ
	Thailand	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	NSR/SUEZ	192.A/173	NSR/SUEZ	SUEZ
Malay Arcipelago	Western Europe	365.U	TPP	70.U/295	TPP/SUEZ					SUEZ
	Northeast Americas	365.U	TPP							SUEZ

Table 31: Summer Routes and Navigable Days (Climatological)

The table shows the origin-destination trades with navigable days (U = unassisted, A = assisted) in the left column and the route in the right. The column ‘conv’ shows the conventional routes that are used when no Arctic routes are navigable. This is the case for the blank cells.

5.2 Aggregated Scenarios

To assess the impact of locations of supply and demand the Aggregated scenarios can be assessed in comparison to the Climatological scenarios. In this section the results from the Aggregated scenarios GSIM runs will be interpreted after which in the next section the two main scenarios will be compared

The initial and post-GSIM trade values for the four navigability scenarios, together with the shares and percentage changes for exporters and importers are shown in table 32 and 33 respectively.

TOTAL VALUES						**SHARES**					**PERCENT CHANGES**			
EXPORTER	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN
Gulf of Mexico	33677	33702	33681	33677	33671	10.17%	10.18%	10.17%	10.17%	10.16%	0.02%	0.09%	0.03%	0.02%
Australia	51149	51555	51410	51506	51612	15.45%	15.58%	15.52%	15.55%	15.58%	-0.90%	-0.11%	-0.39%	-0.21%
Arabian Peninsula	66822	66951	66969	67016	67068	20.18%	20.23%	20.22%	20.23%	20.24%	-0.37%	-0.17%	-0.15%	-0.08%
Northwest America	6951	6974	6990	7005	7022	2.10%	2.11%	2.11%	2.11%	2.12%	-1.00%	-0.68%	-0.46%	-0.24%
Malay Archipelago	52014	52347	52239	52317	52402	15.71%	15.82%	15.77%	15.79%	15.81%	-0.74%	-0.11%	-0.31%	-0.16%
West Africa	22231	22352	22282	22292	22302	6.72%	6.75%	6.73%	6.73%	6.73%	-0.32%	0.22%	-0.09%	-0.05%
Northeast America	16605	16602	16426	16392	16351	5.02%	5.02%	4.96%	4.95%	4.93%	1.55%	1.53%	0.46%	0.25%
Russia Kara	14862	14889	14585	14467	14339	4.49%	4.50%	4.40%	4.37%	4.33%	3.64%	3.83%	1.72%	0.89%
Russia East	17792	16473	17721	17712	17706	5.37%	4.98%	5.35%	5.35%	5.34%	0.49%	-6.96%	0.09%	0.04%
Algeria	11144	11197	11108	11096	11083	3.37%	3.38%	3.35%	3.35%	3.34%	0.54%	1.03%	0.22%	0.12%
East Africa	13605	13644	13638	13649	13661	4.11%	4.12%	4.12%	4.12%	4.12%	-0.41%	-0.12%	-0.16%	-0.09%
East Mediteranean	12826	12865	12847	12852	12858	3.87%	3.89%	3.88%	3.88%	3.88%	-0.25%	0.06%	-0.08%	-0.04%
Caribean	6011	6020	6005	6003	6001	1.82%	1.82%	1.81%	1.81%	1.81%	0.17%	0.33%	0.08%	0.04%
Norway, Hammerfest	3322	3323	3268	3247	3226	1.00%	1.00%	0.99%	0.98%	0.97%	2.99%	3.00%	1.30%	0.67%
Peru	2046	2046	2050	2048	2046	0.62%	0.62%	0.62%	0.62%	0.62%	0.00%	-0.01%	0.18%	0.10%
TOTAL	**331057**	**330939**	**331218**	**331280**	**331347**	100.00%	100.00%	100.00%	100.00%	100.00%	-0.09%	-0.12%	-0.04%	-0.02%

Table 32: Traded Values (million USD), Shares and Percent Changes per Exporter (Aggregated)

TOTAL VALUES						**SHARES**					**PERCENT CHANGES**			
IMPORTER	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN
Arabian Sea	50266	50267	50276	50279	50282	15.18%	15.19%	15.18%	15.18%	15.17%	-0.03%	-0.03%	-0.01%	-0.01%
Argentina/Uruguay	3541	3528	3535	3534	3532	1.07%	1.07%	1.07%	1.07%	1.07%	0.25%	-0.10%	0.10%	0.06%
Baltic	2838	2840	2841	2842	2843	0.86%	0.86%	0.86%	0.86%	0.86%	-0.19%	-0.11%	-0.07%	-0.03%
Bay of Bengal	12580	12544	12539	12529	12517	3.80%	3.79%	3.79%	3.78%	3.78%	0.50%	0.21%	0.17%	0.09%
Brazil	8358	8356	8355	8354	8353	2.52%	2.52%	2.52%	2.52%	2.52%	0.06%	0.04%	0.03%	0.01%
Chile	8027	8009	8023	8021	8019	2.42%	2.42%	2.42%	2.42%	2.42%	0.10%	-0.13%	0.05%	0.03%
China/Taiwan	76484	76491	76586	76621	76660	23.10%	23.11%	23.12%	23.13%	23.14%	-0.23%	-0.22%	-0.10%	-0.05%
GoM, Carribean	2706	2705	2705	2705	2704	0.82%	0.82%	0.82%	0.82%	0.82%	0.04%	0.02%	0.02%	0.01%
Japan	65837	65815	65944	65996	66055	19.89%	19.89%	19.91%	19.92%	19.94%	-0.33%	-0.36%	-0.17%	-0.09%
Malay Archipelago/SEA	15104	15104	15111	15113	15116	4.56%	4.56%	4.56%	4.56%	4.56%	-0.08%	-0.08%	-0.03%	-0.01%
Mediteranean/Ukraine	38931	38930	38883	38858	38829	11.76%	11.76%	11.74%	11.73%	11.72%	0.26%	0.26%	0.14%	0.07%
Mexican Westcoast	460	460	461	461	461	0.14%	0.14%	0.14%	0.14%	0.14%	-0.30%	-0.28%	-0.13%	-0.07%
Northeast America	1574	1574	1573	1572	1572	0.48%	0.48%	0.47%	0.47%	0.47%	0.14%	0.10%	0.04%	0.03%
South Korea	27562	27516	27569	27572	27575	8.33%	8.31%	8.32%	8.32%	8.32%	-0.05%	-0.21%	-0.02%	-0.01%
South/East Africa	1252	1252	1253	1253	1253	0.38%	0.38%	0.38%	0.38%	0.38%	-0.03%	-0.03%	-0.01%	0.00%
Western Europe	15539	15550	15565	15572	15577	4.69%	4.70%	4.70%	4.70%	4.70%	-0.25%	-0.18%	-0.08%	-0.04%
TOTAL	**331057**	**330939**	**331218**	**331280**	**331347**	100.00%	100.00%	100.00%	100.00%	100.00%	-0.09%	-0.12%	-0.04%	-0.02%

Table 33: Traded Values (million USD), Shares and Percent Changes per Importer (Aggregated)

When looking at the percent changes in traded value per exporter it is evident that the exporters located close to the NSR considerably trade more and at higher prices (see tables 32, 33 and 35) when the ice retreats. Especially the Kara region would enjoy an increase in traded value from the higher navigability (+1.72% in the ML case, approx. $246 million). Together with Hammerfest, Norway (+1.30% in the ML case, approx. $42 million) and Northeast Americas (+0.46% in the ML case, approx. $75 million) these account for the largest relative increases. Eastern Russia (+0.09% in the ML case) also an increase in traded values but the initial established trade relations that might benefit from lower costs from shipping across the Arctic is smaller in relation to their total trade, therefore the impact is smaller. Eastern Russia for example is located very close to the major demand hubs with which it has established a strong LNG trade relation. Trades moving to Europe only account for a small proportion of their total traded value. Remarkable is that traded value of Northwest Americas decreases by 0.46% in the ML case while it could enjoy lower shipping costs from the NWP and the NSR. An explanation for this decrease is that initial trades of NW America were primarily Asia bound which after increased navigability of the Arctic faces stronger competition from Hammerfest, the Kara region and NE America.

ML	Arabian Sea	Argentina/Uruguay	Baltic	Bay of Bengal	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Malay Archipelago/SEA	Mediteranean/Ukraine	Mexican Westcoast	Northeast America	South Korea	South/East Africa	Western Europe
Gulf of Mexico	-0.6	1.1	1.6	2.0	0.2	0.5	-1.6	0.2	-2.5	-1.0	1.7	0.0	0.7	-0.6	-0.3	0.1
Australia	1.2	0.0	0.0	3.8	0.0	0.0	0.2	0.0	-0.8	0.0	0.0	0.0	0.0	0.3	0.7	0.0
Arabian Peninsula	0.2	1.9	2.4	2.8	1.0	1.3	-0.8	0.0	-1.7	-0.2	2.5	0.0	0.0	-0.2	0.1	0.5
Northwest America	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	-0.5	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	3.4	0.0	0.0	-0.2	0.0	-1.1	0.5	0.0	-0.2	0.0	0.1	0.5	0.0
West Africa	0.0	0.0	2.2	2.5	0.8	1.1	-1.1	0.7	-2.0	-0.4	2.2	0.0	0.0	-0.4	0.0	0.3
Northeast America	0.0	-0.9	-0.4	0.0	-1.8	-1.5	-2.1	-1.8	10.3	0.0	-0.4	0.0	-0.4	6.0	-1.4	-1.1
Russia Kara	0.0	-6.7	-6.2	-5.8	0.0	-7.3	39.5	0.0	60.2	0.0	-6.1	0.0	0.0	28.3	-4.3	-4.0
Russia East	-0.4	1.3	37.4	2.2	0.0	0.7	-1.4	0.0	-2.4	0.0	1.8	0.0	0.0	-0.5	-0.1	15.0
Algeria	-1.4	0.0	0.8	1.1	0.0	0.0	-2.5	0.0	-3.4	0.0	0.8	0.0	0.0	-1.1	-0.7	-0.4
East Africa	0.3	2.0	2.5	2.8	1.1	1.4	-0.8	0.0	-1.7	-0.1	2.5	0.0	0.0	-0.2	0.2	0.5
East Mediteranean	0.0	1.6	2.2	2.5	0.0	1.1	-1.1	0.7	-2.0	0.0	2.2	0.0	0.0	-0.4	0.0	0.3
Caribean	-0.8	0.8	1.4	0.0	0.0	0.3	-1.9	0.0	-2.8	-1.2	1.4	0.0	0.0	-0.8	-0.4	-0.1
Norway, Hammerfest	-6.1	-4.5	-3.9	-3.6	-5.3	-5.0	24.9	0.0	46.2	0.0	-3.9	0.0	0.0	20.9	-3.1	-2.8
Peru	0.0	0.0	0.0	1.3	0.0	0.0	0.0	-0.5	-3.2	-1.6	1.0	0.0	0.0	0.0	0.0	0.0

Table 34: Percent Changes in Trade Quantity per Trade Relation (Climatological)

Table 35 shows strong increases in traded quantity from the Kara region to China/Taiwan (39.5%), Japan (60.2%) and South Korea (28.3%). The same goes for Norway that experienced increases of 25.9% to China/Taiwan, 46.2% to Japan and 41.2% to South Korea. Eastern Russia experienced an increase in trade to the Baltic (37.4%) and Western Europe (15%). Note that in opposed to the Climatological scenarios, Eastern Russia had some trade to Western Europe in the initial situation due to the increased liquefaction capacity in Vladivostok and higher demand in the European regions. In absolute terms are not as large as the aforementioned figures imply since the share of Eastern Russian LNG that is destined for Europe is relatively small.

Northeast America experienced 10.3% increase in traded quantity to Japan and 6% increase to South Korea while it experienced slight reduction in traded quantity to the other trading partners including China/Taiwan (-2.1%). The reason for the reduction in China/Taiwan bound traded quantity is because it experiences no cost reduction from the NWP and will still be using the Panama Canal. Some Eastern American trade will therefore divert from China/Taiwan to Japan and South Korea since they have become more attractive destinations.

The strong decrease in supply to Europe from Norway and the Kara region is partially taken over by the Arabian Peninsula, East Africa, West Africa, East Mediterranean and Eastern Russia.

For a better assessment of the impacts on importers and exporters the welfare effects, shown in table 35 and figures 15 and 16, are interpret.

MOST LIKELY

Importers	CS	Price	**Exporters**	PS	Price
Arabian Sea	20.73	-0.036%	Gulf of Mexico	7.55	0.022%
Argentina/Uruguay	-6.12	0.133%	Australia	-87.57	-0.157%
Baltic	-5.97	0.199%	Arabian Peninsula	-41.15	-0.058%
Bay of Bengal	-31.54	0.230%	Northwest America	-14.09	-0.182%
Brazil	-4.85	0.046%	Malay Archipelago	-70.13	-0.124%
Chile	-8.23	0.080%	West Africa	-7.71	-0.033%
China/Taiwan	121.65	-0.143%	Northeast America	34.03	0.225%
GoM, Carribean	-0.94	0.043%	Russia Kara	109.90	0.803%
Japan	182.95	-0.236%	Russia East	0.71	0.004%
Malay Archipelago/SEA	13.42	-0.080%	Algeria	11.30	0.106%
Mediteranean/Ukraine	-78.29	0.199%	East Africa	-9.32	-0.065%
Mexican Westcoast	0.88	-0.150%	East Mediteranean	-4.24	-0.031%
Northeast America	-0.87	0.155%	Caribean	3.08	0.047%
South Korea	34.52	-0.105%	Norway, Hammerfest	18.71	0.577%
South/East Africa	0.40	-0.030%	Peru	1.80	0.088%
Western Europe	-2.65	0.024%			
Total Consumer Surplus	235.08		Total Producer Surplus	-47.13	
NET WELFARE EFFECT					187.95

Table 35: Welfare Effects (million USD) and Price Changes for the A-ML scenario

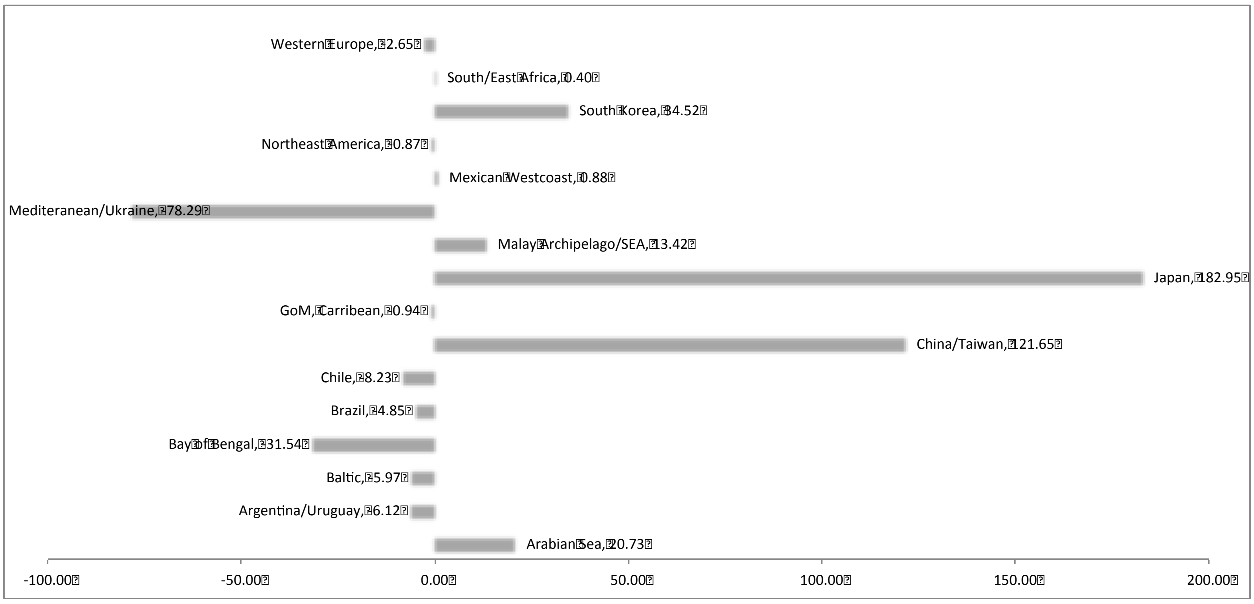


Figure 15: Consumer Surplus A-ML (million USD)

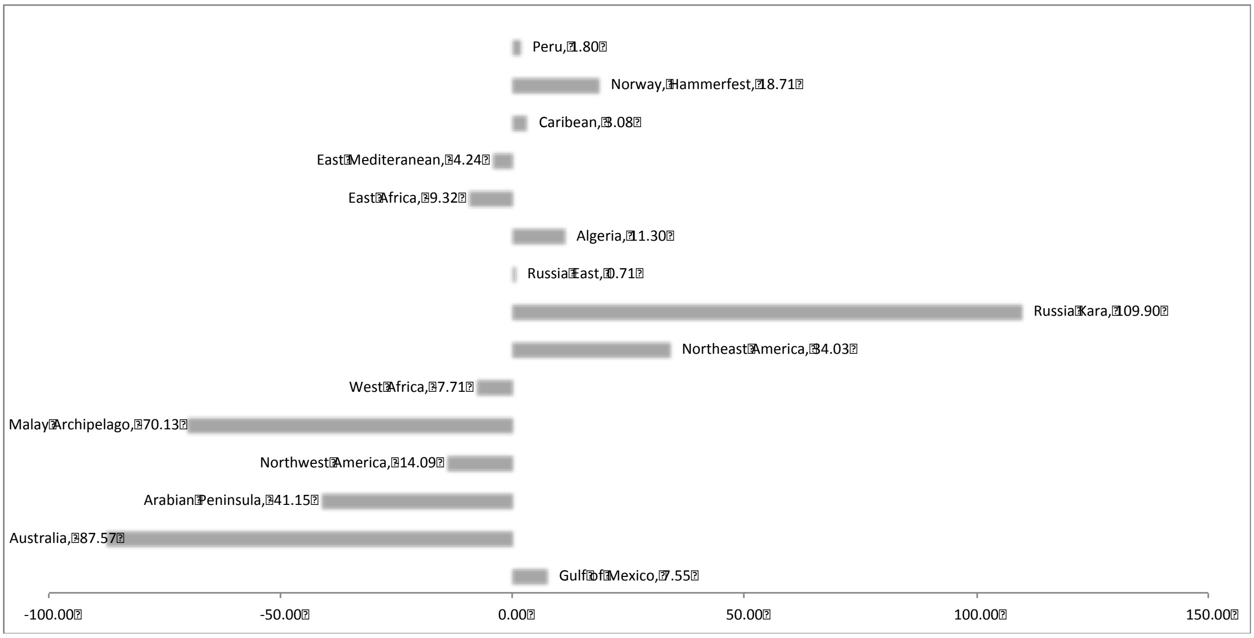


Figure 16: Producer Surplus A-ML (million USD)

Starting with the consumer surplus, it is clear that Japan (approx. $183 million) and China/Taiwan (approx. $123 million) enjoy by far the largest increase in surplus. This is attributable to direct cost advantages on imports from Hammerfest, the Kara region and Northwest Americas, which are transported on the Arctic routes (see table 36). The Arabian Sea as an importer enjoys lower prices due to excess supply in the region that was in the initial situation bound for the three main Asian markets but overtaken by transarctic trade when navigability increases.

The sharp reduction in consumer surplus for the Mediterranean/Ukraine market (approx. -$78 million) is attributable to the shift of Norwegian, Northeast American and Russian Kara supply towards the Asian markets. This results in an increase in consumer prices for the Mediterranean/Ukraine. For the Baltic the price effect is similar (see table 25) but since the market is much smaller the absolute effect is also small. Also has the Baltic a fairly diversified supply portfolio and enjoys cheaper imports from Eastern Russia. The price effect on Western Europe is small since these countries have a very diversified supply of LNG and are not very dependent on the aforementioned suppliers.

The gain in producer surplus (+$110m) and price effect (+0.8%) for the Kara region is the highest since it is a large supplier combined with its location high in the Arctic. Eastern Russia's positive effects from better access to European markets is offset by increased competition in the Asian markets. Other suppliers that enjoy significantly higher prices are Northeast America (+$34m PS, prices +0.18%) and Hammerfest, Norway (+$19m PS, prices +0.58%). Algeria enjoys an increase in producer surplus since it takes over some of the supply left by Norway, Kara and Northeast America at higher than initial prices (+0.1%). The same goes to a lesser extend for Peru, Caribbean and the Gulf of Mexico.

Australia (-$89m) and the Malay Archipelago (-$70m) are in terms of producer surplus the biggest losers. The three Asian importers are by far their most important customers and they are among the largest exporters worldwide. The price effect of increased competition for these producers is -0.16% and -0.12% respectively. The Arabian Peninsula experienced a reduction in surplus of $41 million and a price effect of -0.06%. The reason for the smaller impact on Arabian Peninsula's surplus is that their exports are more diversified.

When comparing these impacts on the HN and the LN scenario, the large spread should be mentioned. In the LN scenario total consumer surplus is estimated at $122m and the producer surplus at -$25m while in the HN scenario the consumer surplus is estimated at $537m and the producer surplus at -$83m. This gives a total (rounded off) range of welfare effects from $97m to $455m (see appendix 12)

NSR trade	Arabian Sea	Argentina/Uruguay	Baltic	Bay of Bengal	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Malay Archipelago/SEA	Mediteranean/Ukraine	Mexican Westcoast	Northeast America	South Korea	South/East Africa	Western Europe	TOTALS
Gulf of Mexico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Australia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arabian Peninsula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northwest America	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malay Archipelago	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
West Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northeast America	-	-	-	-	-	-	-	-	494	-	-	-	-	90	-	-	584
Russia Kara	-	-	-	-	-	-	764	-	1,580	-	-	-	-	270	-	-	2,613
Russia East	-	-	202	-	-	-	-	-	-	-	-	-	-	-	-	439	642
Algeria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Mediteranean	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caribean	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Norway, Hammerfest	-	-	-	-	-	-	341	-	223	-	-	-	-	39	-	-	603
Peru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	-	-	202	-	-	-	1,104	-	2,297	-	-	-	-	399	-	439	**4,442**
NWP trade																	
Gulf of Mexico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Australia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arabian Peninsula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northwest America	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malay Archipelago	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
West Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Northeast America	-	-	-	-	-	-	445	-	1,007	-	-	-	-	183	-	-	1,635
Russia Kara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Russia East	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Algeria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
East Mediteranean	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caribean	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Norway, Hammerfest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Peru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	-	-	-	-	-	-	445	-	1,007	-	-	-	-	183	-	-	**1,635**

Table 36: Transarctic Trade (million USD) in the A-ML Scenario

The following tables give an overview of the share of transarctic trade by exporter and importer for the NSR and the NWP respectively.

NSR

EXPORTER	NI	HN	ML	LN	NI	HN	ML	LN
Gulf of Mexico	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Australia	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Arabian Peninsula	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Northwest America	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Malay Archipelago	0	0	0	0	0.00%	0.00%	0.00%	0.00%
West Africa	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Northeast America	0	672	584	0	0.00%	6.84%	13.14%	0.00%
Russia Kara	5824	5635	2613	1164	61.05%	57.34%	58.84%	66.57%
Russia East	1926	1780	642	301	20.19%	18.12%	14.45%	17.23%
Algeria	664	654	0	0	6.96%	6.66%	0.00%	0.00%
East Africa	0	0	0	0	0.00%	0.00%	0.00%	0.00%
East Mediteranean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Caribean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Norway, Hammerfest	1126	1086	603	283	11.80%	11.05%	13.57%	16.20%
Peru	0	0	0	0	0.00%	0.00%	0.00%	0.00%
TOTAL	**9540**	**9827**	**4442**	**1748**	100.00%	100.00%	100.00%	100.00%

Table 37: NSR Trade Flows (million USD) and Shares per Exporter (Aggregated)

NSR

IMPORTER	NI	HN	ML	LN	NI	HN	ML	LN
Arabian Sea	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Argentina/Uruguay	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Baltic	274	260	202	94	2.87%	2.64%	4.56%	5.38%
Bay of Bengal	2969	2941	0	0	31.12%	29.92%	0.00%	0.00%
Brazil	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Chile	0	0	0	0	0.00%	0.00%	0.00%	0.00%
China/Taiwan	1830	1758	1104	516	19.19%	17.89%	24.87%	29.51%
GoM, Carribean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Japan	2370	2820	2297	793	24.84%	28.69%	51.71%	45.39%
Malay Archipelago/SEA	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Mediteranean/Ukraine	1008	955	0	0	10.56%	9.72%	0.00%	0.00%
Mexican Westcoast	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Northeast America	0	0	0	0	0.00%	0.00%	0.00%	0.00%
South Korea	444	529	399	138	4.66%	5.38%	8.97%	7.88%
South/East Africa	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Western Europe	644	565	439	207	6.75%	5.75%	9.89%	11.85%
TOTAL	**9540**	**9827**	**4442**	**1748**	100.00%	100.00%	100.00%	100.00%

Table 38: NSR Trade Flows (million USD) and Shares per Importer (Aggregated)

NWP

EXPORTER	NI	HN	ML	LN	NI	HN	ML	LN
Gulf of Mexico	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Australia	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Arabian Peninsula	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Northwest America	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Malay Archipelago	0	0	0	0	0.00%	0.00%	0.00%	0.00%
West Africa	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Northeast America	3239	2034	1635	891	100.00%	100.00%	100.00%	100.00%
Russia Kara	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Russia East	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Algeria	0	0	0	0	0.00%	0.00%	0.00%	0.00%
East Africa	0	0	0	0	0.00%	0.00%	0.00%	0.00%
East Mediteranean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Caribean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Norway, Hammerfest	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Peru	0	0	0	0	0.00%	0.00%	0.00%	0.00%
TOTAL	**3239**	**2034**	**1635**	**891**	0.00%	100.00%	100.00%	100.00%

Table 39: NWP Trade Flows (million USD) and Shares per Exporter (Aggregated)

NWP

IMPORTER	NI	HN	ML	LN	NI	HN	ML	LN
Arabian Sea	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Argentina/Uruguay	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Baltic	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Bay of Bengal	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Brazil	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Chile	0	0	0	0	0.00%	0.00%	0.00%	0.00%
China/Taiwan	883	573	445	252	27.27%	28.18%	27.20%	28.24%
GoM, Carribean	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Japan	1991	1233	1007	541	61.48%	60.61%	61.62%	60.76%
Malay Archipelago/SEA	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Mediteranean/Ukraine	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Mexican Westcoast	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Northeast America	0	0	0	0	0.00%	0.00%	0.00%	0.00%
South Korea	364	228	183	98	11.25%	11.21%	11.18%	11.00%
South/East Africa	0	0	0	0	0.00%	0.00%	0.00%	0.00%
Western Europe	0	0	0	0	0.00%	0.00%	0.00%	0.00%
TOTAL	**3239**	**2034**	**1635**	**891**	100.00%	100.00%	100.00%	100.00%

Table 40: NWP Trade Flows (million USD) and Shares per Importer (Aggregated)

In the ML scenario approx. $4.42 billion is shipped on the NSR and $1.64 billion is shipped on the NWP annually. Approximately $3.3 billion of total transarctic traded value is destined for Japan. See table 36 for estimated traded values between regions over the NSR and NWP in the ML scenario.

The NWP will only be used for Northeast American trades going towards the three major Asian markets. In none of the scenarios will the NWP be used for other trades. Note that the NWP uses both Arctic routes. When the navigable season of the NWP closes trades will move over the NSR, which has almost year-round navigability.

The NSR however will be used more extensively in any scenario. Remarkable is that Northeast America trade is shipped on both the NWP as well as the NSR in the ML scenario. The reason for this is that the NSR is navigable for a longer period but the NWP is, if navigable, more economical. These trades will therefore go over the NWP as long as navigability allows so and will use the NSR and the conventional route for the other days.

ROUTE	NI	HN	ML	LN	INITIAL	NI	HN	ML	LN	INITIAL
Direct	267862	268367	269546	269979	270444	77.23%	77.37%	77.69%	77.80%	77.92%
Panama	15089	15371	15440	16720	17543	4.35%	4.43%	4.45%	4.82%	5.05%
Horn	19173	19229	19359	19443	19536	5.53%	5.54%	5.58%	5.60%	5.63%
Hope	1606	1599	1581	1573	1564	0.46%	0.46%	0.46%	0.45%	0.45%
Suez	30324	30453	34969	36675	38004	8.74%	8.78%	10.08%	10.57%	10.95%
NSR	9540	9827	4442	1748	0	2.75%	2.83%	1.28%	0.50%	0.00%
NWP	3239	2034	1635	891	0	0.93%	0.59%	0.47%	0.26%	0.00%
TOTAL	**346833**	**346881**	**346972**	**347028**	**347090**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 41: Traded Values (million USD) and Shares per Shipping Route (Aggregated)

Table 41 shows the total traded values and shares per sailing route. In the aggregated scenarios a larger role of Arctic LNG shipping can be expected. As shown in the table above this happens mainly at the expense of Suez transits and a minor effect on Panama transits is expected.

When comparing the ML, to the LN and the HN results we see that the use of the Arctic routes gradually increases as navigability increases from 0.50% in the LN case and up to 2.83% in the HN case for the NSR and 0.26% in the LN case and 0.57% in the HN case for the NWP. When looking at the zero ice scenario, we see that, at some point when the NWP becomes more navigable, it will take some share from the NSR. More generally in all scenarios the Suez and Panama Canal transits decrease, naturally the NWP causes this effect for the Panama Canal and the NSR for the Suez Canal.

In the following table an overview is given, based on the tariff equivalents for supply and demand in the Aggregated scenarios, when which route deviation is economical. As shown only 27 of the trade relations could benefit directly from increased navigability in the Arctic. Given the initial situation of maritime LNG trade 13 of these relations benefited from increased navigability in the ML scenario.

ECONOMICAL SAILING DEVIATIONS (SUMMER ROUTES)

		NI		HN		ML		LN		CONV
Northwest Americas	Baltic	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/PAN	PAN
	Mediteranean	365.U	TPP	70.U/295.A	TTP					PAN
	Western Europe	365.U	TPP	70.U/295.A	TTP					PAN
Northeast Americas	China/Taiwan	365.U	NWP	250.A/45.A/70.U	NWP/TPP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/PAN	PAN
	Japan	365.U	NWP	250.A/45.A/70.U	NWP/TPP					PAN
	Malay Archipelago	365.U	NWP	250.A/45.A/70.U	NWP/TPP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/PAN	PAN
	South Korea	365.U	NWP	250.A/45.A/70.U	NWP/TPP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/PAN	PAN
Russia Kara	China/Taiwan	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	Japan	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	Malay Archipelago	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	South Korea	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	Bay of Bengal	365.U	TPP	70.U/295.A	TTP					SUEZ
Eastern Russia	Baltic	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	Gulf of Mexico	365.U	NWP	70.U/295.A	TTP					PAN
	Brazil	365.U	NWP	70.U/295.A	TTP					PAN
	Western Europe	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	NSR/SUEZ	192.A/173	NSR/SUEZ	SUEZ
	Mediteranean	365.U	TPP	70.U/295.A	TTP					SUEZ
	Northeast Americas	365.U	NWP	250.A/45.A/70.U	NWP/TPP					PAN
Algeria	China/Taiwan	365.U	TPP	70.U/295.A	TTP					SUEZ
	Japan	365.U	TPP	70.U/295.A	TTP					SUEZ
	South Korea	365.U	TPP	70.U/295.A	TTP					SUEZ
Hammerfest	China/Taiwan	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	Japan	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	South Korea	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
	Thailand	365.U	TPP	70.U/295.A	TTP	100.U/258.A/7	TPP/NSR	192.A/173	NSR/SUEZ	SUEZ
Malay Arcipelago	Western Europe	365.U	TPP	70.U/295	TPP/SUEZ					SUEZ
	Northeast Americas	365.U	TPP							SUEZ

Table 42: Summer Routes and Navigable Days (Aggregated)

5.3 Scenario Comparison

When comparing the two main scenarios it is evident that the geographical distribution of supply and demand is one of the major determinants of the use of the Arctic routes and the economical impacts resulting from that use. Naturally, the closer actors are located to the Baffin Bay (NWP), the Bering Sea, and/or the Arctic Ocean, the more likely trade will benefit from a reduction in shipping costs as a result of higher navigability in Arctic waters.

Secondly, the market share of producers and consumers at these locations determines the magnitude of the local and global impacts. In both of the scenarios total share of exports was, except for the Kara region, relatively small in comparison to the importer and global share. This results in a small estimated impact even if no ice would be present.

Also, the GSIM model uses initial trade shares in combination to the tariff reductions to determine relative changes in demand. It might be that opening of Arctic routes makes certain trades economically attractive where initially zero trade would exist. These trades are not identified in this analysis but it does not mean that on every trade lane that could benefit from the Arctic routes positive trades would occur. As initial trade values already implied does LNG trade depend on many more aspects than just shipping costs. Otherwise imports form far away regions while there is lots of supply available close to home could not be explained.

In both main scenarios the NWP will only ever be used for trades coming from or going to Northeast America. In the Climatological scenarios the share of NWP trade was non-existent but in the Aggregated scenarios the traded amount (approx. $1.5 billion in the ML case) is significant. This accounts for 0.45% of total traded value globally and is slightly more than the share of trade going around Cape Horn (0.40%).

6. Conclusions

6.1 Summary and Conclusions

Due to rising global temperatures, the feasibility of the Arctic routes as a transit route between the East and the West is improving. Particularly LNG, for which time is essential due to the high value of the cargo and boil-off gasses, is widely considered as a high potential cargo for transarctic shipping. In the case of the Northern Sea Route, sailing distance between Northwest Europe and North East Asia reduces by approximately 40% in comparison to the conventional route transiting the Suez Canal. As sea ice further retreats, shipping routes closer to the North Pole become feasible with ultimately the transpolar route being the shortest possible route from Europe to Asia. The Northwest Passages passes through the Canadian Arctic and possibly being able to compete with the Panama Canal but the route faces harsher ice conditions. Besides distance, other benefits such as avoidance of piracy risk and transit dues may be present for the routes. On the other hand is shipping in the Arctic associated with higher vessel building, operating and insurance costs, as well as the requirement for icebreaker assistance.

It is expected that between 2030 and 2040 the first ice-free summers can be observed and the Russian Federation is investing heavily both in Arctic infrastructure, in terms of icebreakers, pilotage and other adjacent services, as well as Arctic oil and gas exploitation. This indicates that the NSR will likely become a feasible transit route. The NWP is expected to be less developed and faces harsher ice conditions and is therefore expected to be navigable for a shorter period per year.

Several studies have been performed to assess the feasibility of commercial use of the Arctic routes, for LNG as well as for other cargoes. Research concludes that there is great potential for cost advantages using the NSR and to a lesser extend the NWP. However, given economic feasibility, research on the economic impact of open Arctic routes is nearly absent. Knowledge on economic impacts is relevant, for business as well as other stakeholders, to understand the scope of it’s potential and to whom the Arctic routes are relevant.

This thesis was aimed at identifying the economic impacts of more navigable Arctic shipping routes on global maritime LNG trade in terms of deviations in trade patterns, prices, traded values, relative use of sea routes and welfare effects. As guidance for the research the following research question had been used:

What is the economic impact of open Arctic routes on global maritime LNG trade?

For the analysis the Global Simulation Model (GSIM) has been used to simulate LNG trade for 2040 after a certain extend of openness of the Arctic routes represented by three feasible scenarios; ‘low navigability’, ‘high navigability’ and ‘most likely navigability’. To put these scenarios further into perspective a fourth navigability scenario is added where zero sea ice is assumed. The GSIM model, developed by Francois and Hall (2002), is an industry-level, multi region, partial-equilibrium trade simulation model originally designed to simulate impacts of trade policy changes. The tariff equivalent used in the model is a share of total value with which prices are increased due to a trade barrier. In the initial situation the tariff equivalent of the Arctic routes is at a prohibitive level meaning that navigable conditions are not sufficient to accommodate a reliable shipping route. The final tariff equivalents are made according to the navigability scenarios with several trade relations enjoying reduction in shipping costs due to increased navigability in the Arctic.

From the literature, 100 days of unassisted and year round assisted navigability on the Northern Sea Route passing mostly outside Russian territorial waters is estimated for 2040 for the ‘most likely’ case. For the Northwest Passages 250 assisted navigable days is estimated.

The navigability scenarios have been analysed in combination with two main scenarios; the climatological and the aggregated scenario. In the climatological scenario, trade flows according to current facilities of supply and demand are used for the base case. The aggregated scenario takes into account new production and import capacity estimated for 2040 creating several different regions among which the Kara region in the Russian Arctic as an export hub, a strong increase of Australian LNG production and the shift for the US from importer to exporter. The split between the two scenarios was made to identify the importance new supply and demand. The findings presented hereafter are based on the ‘most likely’ simulation outputs.

For the current LNG market situation (climatological scenario), the impact of increased navigability would be negligible since at current locations only trades from Hammerfest to Asia, which is a very small share of total trade, benefit from cost reductions. Even in the most favourable navigability scenario, the impacts are marginal. This means that if navigability on the short run would increase, impacts on global maritime LNG markets would still remain negligible. The only players that enjoy trading cost benefits would be Norway as a supplier, enjoying an increase in prices of 0.766% and an absolute increase in producer surplus of $16 million, and China/Taiwan, Japan and South Korea as consumers.

Taking future projects into consideration the use of arctic routes is likely to become a significant trading route. As concluded in the previous section, are the locations and market shares of supply and demand hubs economically close to the Arctic of determining importance. In the climatological scenarios half as much trade relations (7) could benefit from the increased navigability in the ML case than in the aggregated scenario, where 14 trade relations could enjoy reductions in shipping costs. This translates into strong increases in trade from Norway, Northeast America and the Kara region to the three major Asian markets, namely Japan, China/Taiwan and North Korea.

The total consumer surplus is expected to increase by approximately $235 million while the total producer surplus decreases by approximately $47 million, leaving a net welfare effect of $188 million. There is quite a large spread in the estimations of welfare effects over the different navigability scenarios. The low navigability net welfare effect is estimated at $97m while in the high navigability scenario an increase in welfare of $455m is estimated.

In terms of consumer surplus, Japan (approx. $183 million) and China/Taiwan (approx. $122 million) enjoy by far the largest gain. This is attributable to direct cost advantages on imports from Hammerfest, the Kara region and Northwest Americas that use the shorter Arctic routes. The Arabian Sea, as an importer, enjoys lower prices due to supply in the region that was initially bound for the three main Asian markets but were overtaken by transarctic trade.

The sharp reduction (approx. -$78 million) in consumer surplus for the Mediterranean/Ukraine market is expected due to the shift of Norwegian, Northeast American and Russian Kara supply towards the Asian markets. This results in an increase in consumer prices (+0.2%) for the Mediterranean/Ukraine. The same price effect is observed for the Baltic but since the market is much smaller the absolute effect is also small. Also does the Baltic enjoy a small positive effect from NSR imports from Eastern Russia. The price effect on Western Europe is small since these countries have a very diversified supply of LNG and are not very dependent on the aforementioned suppliers.

The gain in producer surplus (+$110m) and price effect (+0.8%) for the Kara region is the highest since it is a large supplier combined with its location high in the Arctic. Eastern Russia's positive effect from better access to European markets is offset by increased competition in the Asian markets. Other suppliers that enjoy significantly higher prices are Northeast America (+34m PS, prices +0.18%) and Hammerfest, Norway (+$19m PS, prices +0.58%). Algeria enjoys a strong increase in producer surplus since it faces less competition for the European market. Peru, Caribbean and the Gulf of Mexico also enjoy slightly higher prices and a gain in producer surplus.

Australia (-$88m) and the Malay Archipelago (-$70m) are in absolute values the biggest losers. The three Asian importers are by far their most important customers. The price effect of the increased competition for these producers is -0.16% and -0.12% respectively. The Arabian Peninsula experienced a reduction in surplus of $41 million and a price effect of -0.06%. The reason for the smaller impact on Arabian Peninsula's surplus is due to a more diversified export portfolio.

1.28% of total traded value is expected to transit the Northern Sea Route and 0.47% will transit the NWP, taking off a slight market share from primarily the Panama and Suez Canal. The total value transiting the NSR annually is estimated at $4.44 billion and the total value transiting the NWP annually is estimated at $1.64 billion. Most of these trades are bound for Japan ($2.3b NSR, $1b NWP) and China/Taiwan ($764m NSR, $445 NWP) and coming from primarily the Kara region ($2.6b) over the Northern Sea Route and Northeast America ($1.64b) over the Northwest

Passage. Northeast America is the only exporter for which the use of the NWP might be the most economical alternative. When the NWP is not navigable the NSR will be used for the same trades.

Given the aforementioned observations is safe to conclude that, provided that the expected new import and export capacity will be developed, especially the NSR and to a lesser extend the NWP will become a significant alternative shipping route. In terms of producer surplus will the Kara region (Russia), Hammerfest (Norway) and Northeast America be the greatest gainers while Australia, the Malay Archipelago and the Arabian Peninsula will face a reduction in surplus. Japan, China/Taiwan and South Korea will be benefit most as customers while the European markets will face a reduction in consumer surplus

6.2 Limitations

Given the scope of this research there has been a necessity to make a lot of assumptions. Especially in the generation of tariff equivalents this has been the case. There have for example three fixed Northern Sea Routes assumed, one passing through Russian national waters, one shorter route (referred to as route 3) passing outside Russian waters and the Transpolar Passage. In reality there are infinitely many routes that move towards and away from the North Pole as the ice melts and grows with the seasons. Also for the generation of initial bilateral trades for the Aggregated scenario assumptions had to be made due to the absence or unavailability of forecasts on bilateral trade.

There are several issues one has to keep in mind when interpreting the results. Most importantly the research has not taken into account the seasonality of natural gas markets. Gas demand in the Northern Hemisphere peaks in winter when gas is used for heating. At the same time the Arctic route experience the lowest, if not zero, navigability. This may result in a lower actual use of the Arctic routes because demand and supply may not be able to meet at the same costs for this route during the winter season.

Also economies of scale are not taken into account. In the analysis a gas carrier with 155.000 cbm capacity is assumed. Arctic vessels generally have these dimensions, partially because draft restrictions on the routes. On oceanic routes however, shippers can enjoy economies of scale with the use of larger (VMax, Qmax) vessels. Also in the Arctic economies of scale may exist. Increased traffic allows for joint use of icebreaker guidance and sailing in convoys. This could substantially reduce the average icebreaker assistance costs.

Finally, the model used makes a simulation of trades based on initial trade shares in combination to the tariff reductions to determine relative changes in demand. It might be that opening of Arctic routes makes certain trades economically attractive where initially zero trade existed due to a high overall trade barrier. These trades are not identified in this analysis. On the other hand, it does not mean that on every trade lane that could benefit from the Arctic routes positive trades would occur.

6.3 Recommendations for Further Research

As explained, the locations of supply and demand are of critical importance to the impact of open Arctic routes. For this research initial trade flows were estimated based on reasoning supported by existing data on import and export capacity growth since forecasts of bilateral trade was lacking. More accurate estimations of future (bilateral) LNG trade based on new supply and demand could strongly improve the accuracy of the estimated impacts of increased Arctic navigability.

Also accurate studies on pricing strategies of the Panama and Suez Canal, taking into account the Arctic routes would valuable. If there is a price effect of increased navigability of Artic routes on the Panama and/or Suez Canal, tariff equivalents of other trade relations are also affected and more spill-over effects could be identified.

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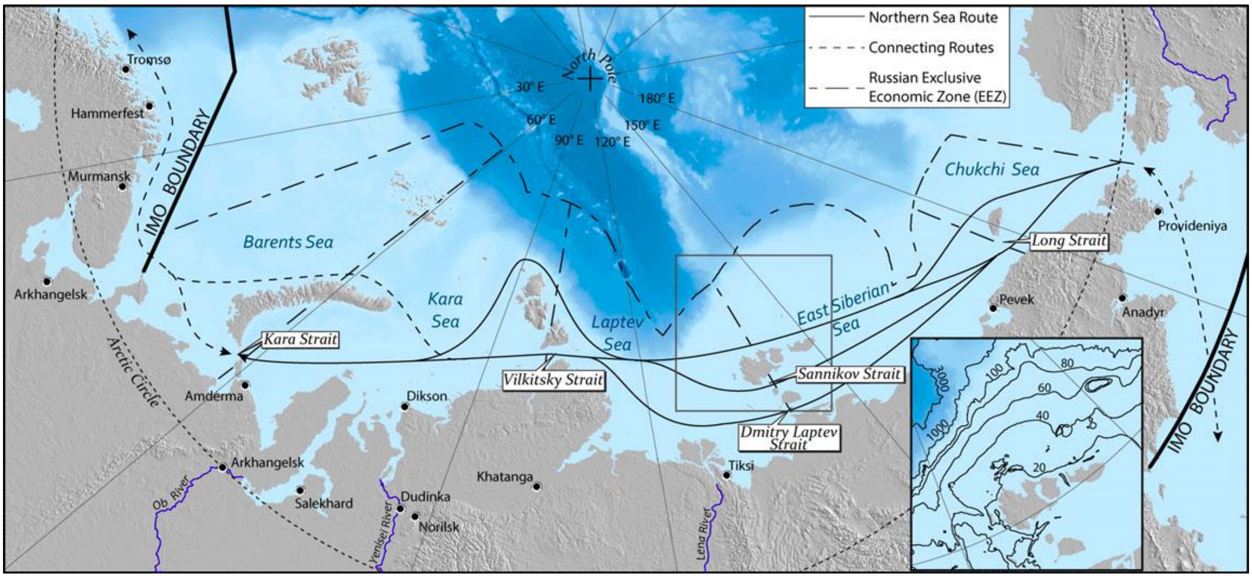
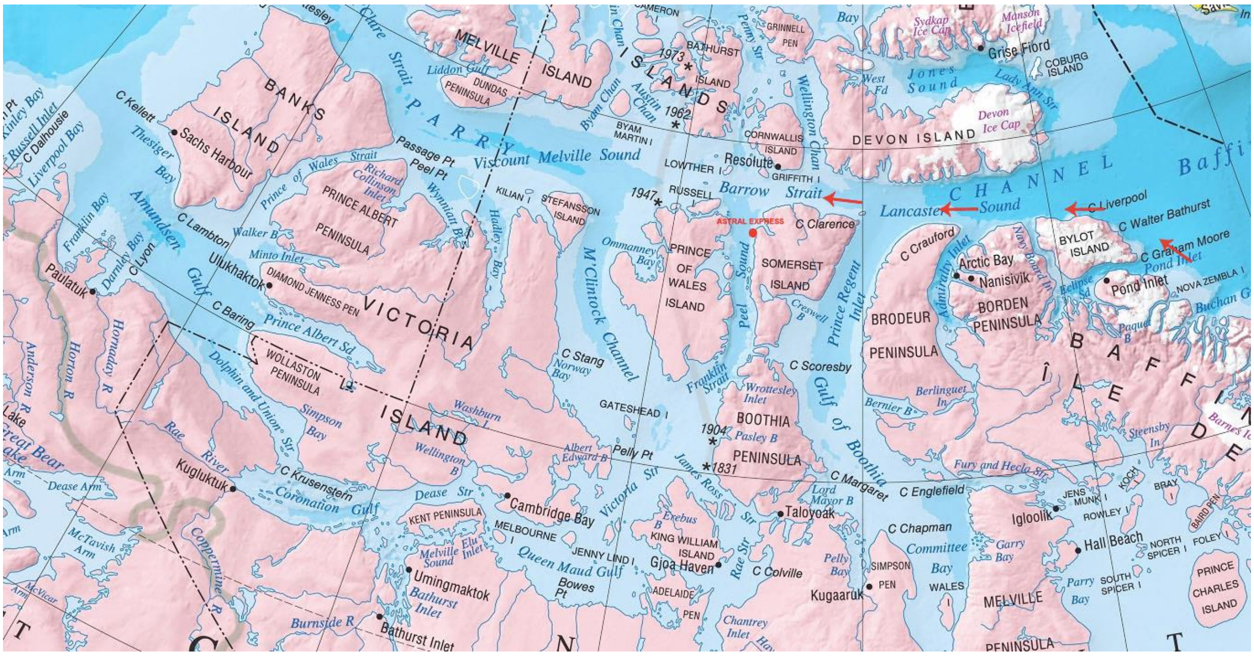
Appendices

Appendix 1: Russian Maritime Arctic Map



Source: Stephenson et. al. (2013)

Appendix 2: Canadian Archipelago



Source: Astral Express (2010)

Appendix 3: Ice Class Classification Conversion Table

Classification Conversion Table				
IMO Polar Class	Finnis-Swedish Ice Class	RMRS	Ice conditions (cm)	Required minimum icebreaking capacity (m)
PC 1	-	-	Muli-year > 400	3
PC 2	-	ARC 9	Multi-year 300 - 400	2.4
PC 3	-	ARC 8	Secon-year 200 - 300	1.8
PC 4	-	ARC 7	First-year 120 - 200	1.3
PC 5	-	ARC 6	First-year 90 - 120	1
PC 6	IA Super	ARC 5 (UL)	First-year 70 - 90	0.7
PC 7	IA	ARC 4 (L1)	First-year 50 - 70	0.5
-	IB	ICE 3	White ice 30 - 50	0.25
-	IC	ICE 2	Grey-white ice 15 - 30	0.25
	Category II	ICE 1	Grey ice 10 - 15	0.15

Source: Tsoy, 2010

Appendix 4: Liquefaction Capacity Map

Data: Clarksons (2013)

Appendix 5: Regasification Capacity Map

Data: Clarksons (2013)

Appendix 6: Initial Consumer Prices (Climatological)

Importer	Price/ton
Arabian Sea	€ 574.45
Argentina	€ 636.51
Brazil	€ 636.51
Chile	€ 627.28
China/Taiwan	€ 553.93
GoM, Carribean	€ 416.22
Japan	€ 582.14
Mediteranean	€ 497.51
Western Europe	€ 342.36
Northeast America	€ 179.52
South Korea	€ 582.14
Thailand	€ 553.93
Mexican Westcoast	€ 627.28

Appendix 7: Initial Consumer Prices (Aggregated)

Importer	price/ton
Arabian Sea	$574.45
Argentina/Uruguay	$636.51
Baltic	$524.00
Bay of Bengal	$524.00
Brazil	$636.51
Chile	$627.28
China/Taiwan	$553.93
GoM, Carribean	$416.22
Japan	$582.14
Malay Archipelago/SEA	$553.93
Mediteranean/Ukraine	$497.51
Mexican Westcoast	$627.28
Northeast America	$179.52
South Korea	$582.14
South/West Africa	$524.00
Western Europe	$342.36

Appendix 8: Traded Values (Climatological Scenarios)

Scenario		Arabian Sea	Argentina	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Mediteranean	Western Europe	Northeast America	South Korea	Thailand	Mexican Westcoast	Totals
INITIAL	Alaska	-	-	-	-	-	-	128	-	-	-	-	-	-	128
	Algeria	386	-	-	-	186	-	112	4724	332	-	41	-	-	5781
	Australia	54	-	-	-	7591	-	10737	-	-	-	572	-	-	18954
	Eastern Russia	-	-	-	-	443	-	5795	-	-	-	1577	-	-	7815
	Egypt	589	57	-	138	866	30	741	696	19	-	470	-	-	3605
	Hammerfest, Norway	172	179	207	41	69	106	249	789	233	-	44	-	-	2088
	Malay Archipelago	-	-	-	-	13878	-	-	-	-	-	9437	-	190	23505
	Arabian Peninsula	11046	65	1568	183	17748	1440	17467	4491	3499	152	13017	701	-	71378
	Peru	-	-	-	-	-	456	533	864	-	-	-	364	-	2216
	Trinidad	225	2344	1596	1642	148	1946	199	460	316	292	697	63	-	9929
	West Africa	1690	-	499	197	2199	409	5247	3014	716	-	1594	79	-	15644
	Totals	14162	2645	3870	2201	43127	4386	41209	15037	5115	445	27449	1207	190	**161043**
LOW	Alaska	-	-	-	-	-	-	128	-	-	-	-	-	-	128
	Algeria	386	-	-	-	185	-	112	4728	332	-	41	-	-	5783
	Australia	54	-	-	-	7594	-	10726	-	-	-	572	-	-	18946
	Eastern Russia	-	-	-	-	443	-	5790	-	-	-	1578	-	-	7811
	Egypt	589	57	-	138	866	30	739	697	19	-	470	-	-	3605
	Hammerfest, Norway	166	173	200	40	77	103	310	762	225	-	53	-	-	2109
	Malay Archipelago	-	-	-	-	13874	-	-	-	-	-	9435	-	190	23499
	Arabian Peninsula	11053	66	1573	183	17740	1442	17432	4503	3506	152	13011	702	-	71364
	Peru	-	-	-	-	-	456	531	865	-	-	-	364	-	2216
	Trinidad	224	2350	1598	1643	147	1946	198	460	316	292	695	63	-	9933
	West Africa	1691	-	500	197	2198	410	5236	3022	717	-	1593	79	-	15642
	Totals	14163	2646	3871	2201	43124	4386	41202	15038	5115	445	27448	1207	190	**161035**
MOST LIKELY	Alaska	-	-	-	-	-	-	128	-	-	-	-	-	-	128
	Algeria	385	-	-	-	185	-	111	4731	332	-	40	-	-	5785
	Australia	54	-	-	-	7596	-	10715	-	-	-	572	-	-	18938
	Eastern Russia	-	-	-	-	443	-	5785	-	-	-	1579	-	-	7807
	Egypt	589	57	-	139	865	30	738	699	19	-	470	-	-	3605
	Hammerfest, Norway	160	168	193	39	86	99	368	737	217	-	62	-	-	2129
	Malay Archipelago	-	-	-	-	13870	-	-	-	-	-	9433	-	190	23493
	Arabian Peninsula	11059	66	1577	184	17731	1445	17400	4515	3512	152	13006	702	-	71350
	Peru	-	-	-	-	-	456	529	867	-	-	-	363	-	2216
	Trinidad	224	2356	1599	1643	147	1945	198	460	316	292	693	63	-	9937
	West Africa	1692	-	502	197	2196	411	5225	3029	718	-	1592	79	-	15640
	Totals	14163	2647	3871	2201	43120	4387	41196	15039	5114	444	27447	1207	190	**161028**
HIGH	Alaska	-	-	-	-	-	-	127	-	-	-	-	-	-	127
	Algeria	381	-	-	-	197	-	143	4704	329	-	49	-	-	5803
	Australia	54	-	-	-	7597	-	10698	-	-	-	573	-	-	18923
	Eastern Russia	-	-	-	-	444	-	5778	-	-	-	1580	-	-	7801
	Egypt	589	58	-	139	863	30	735	703	19	-	469	-	-	3604
	Hammerfest, Norway	152	161	185	37	106	95	431	706	207	-	74	-	-	2154
	Malay Archipelago	-	-	-	-	13861	-	-	-	-	-	9430	-	190	23480
	Arabian Peninsula	11071	67	1584	184	17706	1449	17347	4546	3523	153	12992	702	-	71324
	Peru	-	-	-	-	-	457	527	871	-	-	-	363	-	2217
	Trinidad	224	2364	1601	1643	146	1945	196	462	316	292	691	63	-	9942
	West Africa	1692	-	503	198	2192	411	5205	3048	720	-	1589	79	-	15637
	Totals	14164	2649	3872	2202	43112	4387	41187	15040	5114	444	27445	1207	190	**161012**
NO ICE	Alaska	-	-	-	-	-	-	127	-	-	-	-	-	-	127
	Algeria	382	-	-	-	191	-	136	4714	330	-	47	-	-	5799
	Australia	54	-	-	-	7598	-	10697	-	-	-	573	-	-	18923
	Eastern Russia	-	-	-	-	444	-	5777	-	-	-	1580	-	-	7801
	Egypt	590	58	-	139	863	30	735	703	19	-	469	-	-	3604
	Hammerfest, Norway	151	160	183	37	109	94	442	701	206	-	75	-	-	2158
	Malay Archipelago	-	-	-	-	13861	-	-	-	-	-	9430	-	190	23480
	Arabian Peninsula	11071	67	1584	184	17708	1450	17344	4544	3523	153	12993	702	-	71324
	Peru	-	-	-	-	-	457	527	870	-	-	-	363	-	2217
	Trinidad	224	2365	1601	1644	146	1945	196	462	316	292	690	63	-	9943
	West Africa	1693	-	504	198	2192	412	5205	3046	720	-	1589	79	-	15637
	Totals	14164	2649	3872	2202	43113	4387	41186	15040	5113	444	27445	1207	190	**161013**

Appendix 9: Traded Values (Aggregated Scenarios)

	Arabian Sea	Argentina/Uruguay	Baltic	Bay of Bengal	Brazil	Chile	China/Taiwan	GoM/Carribean	Japan	Malay Archipelago/SEA	Mediteranean/Ukraine	Mexican Westcoast	Northeast America	South Korea	South/East Africa	Western Europe	Totals
INITIAL																	
Gulf of Mexico	2872.24	1273.02	395.77	351.59	4455.56	5018.21	1695.49	1248.66	1287.83	1279.85	5791.93	-	179.52	5350.63	82.90	2826.57	33671
Australia	488.10	-	-	258.74	-	-	27142.67	-	26584.76	-	-	-	-	1440.18	6.54	-	51612
Arabian Peninsula	33864.25	37.63	169.01	63.37	1030.79	244.05	12391.14	-	6894.48	5539.32	3380.04	-	-	5814.37	209.88	1757.86	67068
Northwest America	-	-	-	-	-	-	1661.80	-	5821.42	-	-	250.91	-	-	-	-	7022
Malay Archipelago	-	-	-	813.84	-	-	22149.80	-	15201.85	8308.98	-	301.09	-	9238.96	524.00	-	52402
West Africa	2872.24	-	166.69	1621.18	1329.91	866.82	4431.46	221.76	4657.13	273.40	3482.59	-	-	2551.53	141.00	684.72	22302
Northeast America	-	640.54	224.93	3597.32	1273.02	738.07	675.88	218.71	1358.59	-	3980.10	-	359.03	245.60	51.10	1755.65	16351
Russia Kara	-	318.25	1048.00	2346.29	-	530.51	553.93	-	998.23	-	6307.68	-	-	176.92	35.93	1292.68	14339
Russia East	2525.56	318.25	150.28	2233.58	-	489.23	2769.66	-	6403.56	-	746.27	-	-	2910.71	33.37	342.36	17706
Algeria	1820.58	-	63.78	118.09	-	-	407.74	-	139.52	-	7462.70	-	-	51.38	24.71	521.70	11083
East Africa	5107.73	9.84	64.77	22.24	342.13	64.89	3593.67	-	2017.33	180.93	977.32	-	-	1418.05	67.49	529.83	13661
East Mediteranean	4661.02	143.47	5.90	93.19	-	313.64	3131.75	22.32	1498.37	-	2624.86	-	-	983.58	64.06	48.24	12858
Caribean	509.21	1416.01	29.81	-	1478.66	1254.55	157.10	361.27	120.40	82.68	507.71	-	-	424.50	6.48	236.44	6001
Norway, Hammerfest	401.49	133.00	524.00	324.99	236.22	79.24	276.97	-	154.96	-	883.62	-	-	27.85	5.37	181.50	3226
Peru	-	-	-	672.61	-	-	-	75.43	245.53	313.87	721.82	-	-	-	-	-	2046
Totals	50282	3532	2843	12517	8353	8019	76660	2704	66055	15116	38829	461	1572	27575	1253	15577	**331347**
LOW																	
Gulf of Mexico	2863.84	1280.44	399.22	355.27	4461.60	5033.05	1681.29	1250.15	1270.67	1273.33	5842.77	-	180.77	5316.75	82.68	2828.39	33677
Australia	490.81	-	-	263.65	-	-	27145.78	-	26456.24	-	-	-	-	1443.28	6.58	-	51506
Arabian Peninsula	33894.01	37.99	171.13	64.28	1036.10	245.70	12334.50	-	6828.82	5532.17	3422.54	-	-	5799.66	210.13	1765.67	67016
Northwest America	-	-	-	-	-	-	1664.04	-	5800.46	-	-	251.12	-	-	-	-	7005
Malay Archipelago	-	-	-	828.00	-	-	22118.16	-	15104.90	8324.36	-	300.51	-	9244.62	526.27	-	52317
West Africa	2871.42	-	168.58	1642.43	1335.22	871.67	4406.04	222.61	4607.36	272.73	3522.34	-	-	2542.11	141.00	686.97	22292
Northeast America	-	637.85	224.63	3598.94	1261.96	732.85	669.10	216.77	1439.78	-	3975.12	-	357.94	260.74	50.45	1739.16	16392
Russia Kara	-	308.47	1018.83	2285.13	-	512.67	668.49	-	1315.81	-	6132.50	-	-	227.95	34.52	1246.22	14467
Russia East	2521.08	320.48	178.70	2259.55	-	491.24	2749.65	-	6325.58	-	753.68	-	-	2895.62	33.32	393.69	17712
Algeria	1808.09	-	64.08	118.86	-	-	402.72	-	137.11	-	7498.82	-	-	50.85	24.55	519.98	11096
East Africa	5113.89	9.94	65.61	22.57	344.00	65.35	3578.43	-	1998.78	180.76	989.93	-	-	1414.93	67.60	532.36	13649
East Mediteranean	4659.34	144.67	5.96	94.40	-	315.37	3113.55	22.41	1482.24	-	2654.62	-	-	979.88	64.06	48.39	12852
Caribean	507.13	1422.63	30.04	-	1478.96	1256.81	155.60	361.28	118.66	82.17	511.58	-	-	421.33	6.46	236.32	6003
Norway, Hammerfest	390.06	130.38	515.20	320.11	230.51	77.45	312.09	-	192.49	-	868.83	-	-	33.76	5.22	176.98	3247
Peru	-	-	-	677.59	-	-	-	75.29	241.50	311.30	725.93	-	-	-	-	-	2048
Totals	50279	3534	2842	12529	8354	8021	76621	2705	65996	15113	38858	461	1572	27572	1253	15572	**331280**
MOST LIKELY																	
Gulf of Mexico	2856.51	1287.19	402.26	358.63	4466.74	5046.63	1668.34	1251.39	1255.35	1267.50	5889.68	-	181.80	5286.65	82.49	2827.46	33681
Australia	493.27	-	-	268.07	-	-	27145.13	-	26342.80	-	-	-	-	1446.13	6.61	-	51410
Arabian Peninsula	33921.91	38.32	172.99	65.09	1040.77	247.18	12281.83	-	6770.22	5525.67	3461.30	-	-	5786.62	210.35	1771.03	66969
Northwest America	-	-	-	-	-	-	1665.77	-	5781.83	-	-	251.31	-	-	-	-	6990
Malay Archipelago	-	-	-	840.81	-	-	22086.88	-	15018.89	8338.17	-	299.99	-	9250.11	528.32	-	52239
West Africa	2870.78	-	170.25	1661.67	1339.85	876.03	4382.55	223.35	4562.87	272.12	3558.63	-	-	2533.71	141.01	688.34	22282
Northeast America	-	635.98	224.51	3603.74	1252.95	728.77	662.83	215.19	1501.41	-	3974.67	-	357.05	272.43	49.91	1724.12	16426
Russia Kara	-	299.26	991.04	2227.32	-	495.93	779.17	-	1611.77	-	5967.85	-	-	275.84	33.21	1201.46	14585
Russia East	2515.91	322.32	206.45	2282.00	-	492.81	2729.91	-	6252.69	-	760.10	-	-	2880.73	33.26	448.42	17721
Algeria	1796.77	-	64.34	119.55	-	-	398.11	-	134.94	-	7532.05	-	-	50.37	24.40	517.90	11108
East Africa	5119.69	10.02	66.34	22.86	345.66	65.76	3564.27	-	1982.26	180.60	1001.44	-	-	1412.19	67.69	534.14	13638
East Mediteranean	4657.86	145.75	6.02	95.50	-	316.92	3096.66	22.48	1467.79	-	2681.73	-	-	976.55	64.05	48.49	12847
Caribean	505.29	1428.64	30.23	-	1479.10	1258.88	154.23	361.26	117.10	81.70	515.16	-	-	418.49	6.44	235.99	6005
Norway, Hammerfest	379.10	127.81	506.31	315.20	224.94	75.71	347.82	-	227.93	-	854.21	-	-	39.41	5.07	172.43	3268
Peru	-	-	-	682.07	-	-	-	75.15	237.87	308.96	729.70	-	-	-	-	-	2050
Totals	50276	3535	2841	12539	8355	8023	76586	2705	65944	15111	38883	461	1573	27569	1253	15565	**331218**
HIGH																	
Gulf of Mexico	2843.88	1303.79	408.40	348.84	4484.78	5078.40	1640.96	1254.89	1230.65	1256.02	5957.84	-	185.48	5232.35	82.17	2828.62	33702
Australia	497.84	-	-	264.44	-	-	27081.42	-	26200.40	-	-	-	-	1451.36	6.68	-	51555
Arabian Peninsula	33981.08	39.04	176.64	63.72	1051.26	250.22	12158.14	-	6680.56	5510.08	3521.70	-	-	5763.41	210.83	1782.52	66951
Northwest America	-	-	-	-	-	-	1663.14	-	5755.10	-	-	251.37	-	-	-	-	6974
Malay Archipelago	-	-	-	827.84	-	-	21993.27	-	14908.85	8362.50	-	299.28	-	9266.30	532.51	-	52347
West Africa	2877.24	-	173.93	1627.33	1354.05	887.26	4340.54	225.44	4504.65	271.49	3622.63	-	-	2524.80	141.40	693.16	22352
Northeast America	-	625.35	221.34	3396.34	1220.29	711.53	836.84	209.30	1799.74	-	3903.62	-	353.78	332.77	48.19	1672.63	16602
Russia Kara	-	283.40	941.46	2589.09	-	465.86	914.49	-	1815.42	-	5645.57	-	-	315.79	30.80	1120.37	14889
Russia East	2494.10	325.13	259.78	2210.36	-	493.84	2673.41	-	6102.61	-	955.36	-	-	2838.83	32.99	565.17	16473
Algeria	1768.20	-	64.61	114.93	-	-	419.26	-	173.10	-	7536.02	-	-	61.88	24.03	512.23	11197
East Africa	5131.91	10.22	67.78	22.39	349.36	66.61	3530.73	-	1957.33	180.21	1019.53	-	-	1407.45	67.89	537.95	13644
East Mediteranean	4659.13	148.29	6.14	93.34	-	320.36	3060.76	22.65	1446.08	-	2724.80	-	-	971.17	64.10	48.73	12865
Caribean	501.47	1442.72	30.60	-	1480.49	1262.93	151.21	361.15	114.41	80.70	519.56	-	-	412.85	6.39	235.35	6020
Norway, Hammerfest	356.18	122.57	487.01	351.58	213.49	72.05	423.89	-	264.17	-	818.32	-	-	46.53	4.77	162.96	3323
Peru	-	-	-	668.03	-	-	-	75.88	234.88	308.33	743.21	-	-	-	-	-	2046
Totals	50267	3528	2840	12544	8356	8009	76491	2705	65815	15104	38930	460	1574	27516	1252	15550	**330939**
Gulf of Mexico	2838.88	1310.69	410.25	350.59	4495.53	5091.52	1631.38	1257.49	1219.62	1251.81	5981.32	-	187.72	5211.63	82.06	2818.38	33677
Australia	499.63	-	-	267.12	-	-	27075.82	-	26117.99	-	-	-	-	1453.60	6.70	-	51149
Arabian Peninsula	34004.10	39.33	177.84	64.19	1056.23	251.44	12118.28	-	6638.36	5505.26	3543.52	-	-	5755.00	211.05	1780.41	66822
Northwest America	-	-	-	-	-	-	1664.00	-	5741.31	-	-	251.49	-	-	-	-	6951
Malay Archipelago	-	-	-	835.45	-	-	21966.30	-	14846.30	8371.83	-	298.90	-	9271.36	534.12	-	52014
West Africa	2877.62	-	175.02	1638.40	1359.73	891.13	4323.84	226.31	4473.56	271.10	3643.20	-	-	2519.71	141.47	691.96	22231
Northeast America	-	617.15	218.29	3348.37	1200.07	699.97	883.24	205.76	1991.48	-	3847.17	-	351.75	364.48	47.19	1634.06	16605
Russia Kara	-	279.93	929.23	2612.68	-	458.54	962.80	-	1916.03	-	5567.94	-	-	332.69	30.15	1094.31	14862
Russia East	2481.69	325.85	274.01	2214.38	-	493.57	2648.95	-	6027.36	-	1007.83	-	-	2818.31	32.84	644.42	17792
Algeria	1760.09	-	64.74	115.20	-	-	423.99	-	176.76	-	7546.21	-	-	62.95	23.93	508.92	11144
East Africa	5136.86	10.30	68.26	22.56	351.10	66.96	3520.21	-	1945.57	180.11	1026.12	-	-	1405.81	67.98	537.47	13605
East Mediteranean	4659.24	149.32	6.18	93.97	-	321.73	3048.62	22.73	1435.92	-	2740.03	-	-	969.10	64.13	48.64	12826
Caribean	499.88	1448.46	30.70	-	1482.03	1264.49	150.10	361.41	113.21	80.32	520.92	-	-	410.62	6.37	234.17	6011
Norway, Hammerfest	349.96	121.48	482.32	356.11	210.82	71.17	443.64	-	277.27	-	809.86	-	-	48.74	4.69	159.80	3322
Peru	-	-	-	670.54	-	-	-	75.95	232.47	306.91	745.25	-	-	-	-	-	2046
Totals	50266	3541	2838	12580	8358	8027	76484	2706	65837	15104	38931	460	1574	27562	1252	15539	**331057**

Appendix 10: Welfare Effects C-LN, C-HN, C-NI

NO ICE

Importers	CS	Price	Exporters	PS	Price
Arabian Sea	0.62	-0.004%	Alaska	-0.11	-0.084%
Argentina	-3.81	0.140%	Algeria	7.19	0.124%
Brazil	-3.20	0.078%	Australia	-12.55	-0.066%
Chile	-1.41	0.061%	Eastern Russia	-5.70	-0.073%
China/Taiwan	22.79	-0.050%	Egypt	-0.50	-0.014%
GoM, Carribean	-2.11	0.044%	Hammerfest, Norway	27.81	1.319%
Japan	43.32	-0.099%	Malay Archipelago	-9.75	-0.042%
Mediteranean	-15.10	0.096%	Arabian Peninsula	-21.37	-0.030%
Western Europe	-2.44	0.043%	Peru	0.38	0.017%
Northeast America	-0.11	0.022%	Trinidad	5.47	0.055%
South Korea	13.93	-0.048%	West Africa	-2.85	-0.018%
Thailand	0.13	-0.010%			
Mexican Westcoast	0.09	-0.042%			
Total Consumer Surplus	52.69		Total Producer Surplus	-11.99	
NET WELFARE EFFECT					40.70

HIGH

Importers	CS	Price	Exporters	PS	Price
Arabian Sea	0.63	-0.004%	Alaska	-0.11	-0.083%
Argentina	-3.69	0.132%	Algeria	8.87	0.153%
Brazil	-3.00	0.073%	Australia	-12.53	-0.066%
Chile	-1.36	0.058%	Eastern Russia	-5.67	-0.073%
China/Taiwan	23.33	-0.052%	Egypt	-0.48	-0.013%
GoM, Carribean	-1.98	0.042%	Hammerfest, Norway	26.37	1.251%
Japan	42.82	-0.098%	Malay Archipelago	-9.98	-0.042%
Mediteranean	-15.94	0.101%	Arabian Peninsula	-21.46	-0.030%
Western Europe	-2.37	0.042%	Peru	0.41	0.018%
Northeast America	-0.10	0.020%	Trinidad	5.17	0.052%
South Korea	14.25	-0.049%	West Africa	-2.74	-0.018%
Thailand	0.12	-0.009%			
Mexican Westcoast	0.09	-0.042%			
Total Consumer Surplus	52.80		Total Producer Surplus	-12.16	
NET WELFARE EFFECT					40.64

LOW

Importers	CS	Price	Exporters	PS	Price
Arabian Sea	0.15	-0.001%	Alaska	-0.03	-0.023%
Argentina	-1.17	0.042%	Algeria	0.84	0.014%
Brazil	-0.98	0.024%	Australia	-3.35	-0.018%
Chile	-0.43	0.018%	Eastern Russia	-1.56	-0.020%
China/Taiwan	5.49	-0.012%	Egypt	-0.14	-0.004%
GoM, Carribean	-0.64	0.014%	Hammerfest, Norway	8.23	0.393%
Japan	11.96	-0.027%	Malay Archipelago	-2.40	-0.010%
Mediteranean	-3.47	0.022%	Arabian Peninsula	-5.61	-0.008%
Western Europe	-0.69	0.012%	Peru	0.08	0.003%
Northeast America	-0.04	0.007%	Trinidad	1.64	0.017%
South Korea	3.54	-0.012%	West Africa	-0.83	-0.005%
Thailand	0.04	-0.003%			
Mexican Westcoast	0.02	-0.010%			
Total Consumer Surplus	13.79		Total Producer Surplus	-3.13	
NET WELFARE EFFECT					10.66

Appendix 11: Welfare Effects A-LN, A-HN, A-NI

NO ICE

Importers	CS	Price	**Exporters**	PS	Price
Arabian Sea	50.77	-0.089%	Gulf of Mexico	11.65	0.034%
Argentina/Uruguay	-15.23	0.331%	Australia	-199.94	-0.359%
Baltic	-12.89	0.429%	Arabian Peninsula	-100.44	-0.141%
Bay of Bengal	-0.33	0.002%	Northwest America	-30.91	-0.401%
Brazil	-12.99	0.122%	Malay Archipelago	-165.63	-0.294%
Chile	-19.01	0.185%	West Africa	-26.93	-0.116%
China/Taiwan	301.44	-0.354%	Northeast America	116.32	0.765%
GoM, Carribean	-2.27	0.104%	Russia Kara	230.92	1.676%
Japan	392.99	-0.507%	Russia East	18.55	0.098%
Malay Archipelago/SEA	33.03	-0.197%	Algeria	29.05	0.273%
Mediteranean/Ukraine	-148.48	0.377%	East Africa	-22.77	-0.158%
Mexican Westcoast	2.00	-0.341%	East Mediteranean	-12.31	-0.091%
Northeast America	-2.88	0.515%	Caribean	7.15	0.108%
South Korea	79.36	-0.242%	Norway, Hammerfest	42.75	1.311%
South/East Africa	0.97	-0.072%	Peru	0.75	0.037%
Western Europe	-0.21	0.002%			
Total Consumer Surplus	646.27		Total Producer Surplus	-101.80	
NET WELFARE EFFECT					544.47

HIGH

Importers	CS	Price	**Exporters**	PS	Price
Arabian Sea	41.56	-0.073%	Gulf of Mexico	10.92	0.032%
Argentina/Uruguay	-12.61	0.274%	Australia	-167.47	-0.300%
Baltic	-11.31	0.377%	Arabian Peninsula	-82.78	-0.116%
Bay of Bengal	7.06	-0.051%	Northwest America	-25.79	-0.334%
Brazil	-10.19	0.096%	Malay Archipelago	-139.14	-0.247%
Chile	-15.99	0.155%	West Africa	-22.59	-0.097%
China/Taiwan	254.06	-0.298%	Northeast America	85.35	0.562%
GoM, Carribean	-1.76	0.080%	Russia Kara	205.99	1.497%
Japan	327.03	-0.422%	Russia East	11.49	0.061%
Malay Archipelago/SEA	27.58	-0.165%	Algeria	25.64	0.241%
Mediteranean/Ukraine	-130.85	0.332%	East Africa	-18.75	-0.130%
Mexican Westcoast	1.67	-0.285%	East Mediteranean	-9.94	-0.073%
Northeast America	-2.13	0.381%	Caribean	6.00	0.091%
South Korea	66.60	-0.203%	Norway, Hammerfest	37.80	1.160%
South/East Africa	0.81	-0.061%	Peru	0.43	0.021%
Western Europe	-4.15	0.038%			
Total Consumer Surplus	537.39		Total Producer Surplus	-82.83	
NET WELFARE EFFECT					454.56

LOW

Importers	CS	Price	**Exporters**	PS	Price
Arabian Sea	10.81	-0.019%	Gulf of Mexico	4.19	0.012%
Argentina/Uruguay	-3.23	0.070%	Australia	-45.86	-0.082%
Baltic	-3.19	0.106%	Arabian Peninsula	-21.39	-0.030%
Bay of Bengal	-16.59	0.121%	Northwest America	-7.40	-0.096%
Brazil	-2.65	0.025%	Malay Archipelago	-36.67	-0.065%
Chile	-4.37	0.042%	West Africa	-3.97	-0.017%
China/Taiwan	63.09	-0.074%	Northeast America	18.71	0.124%
GoM, Carribean	-0.52	0.024%	Russia Kara	56.91	0.417%
Japan	96.28	-0.124%	Russia East	-0.09	0.000%
Malay Archipelago/SEA	6.99	-0.042%	Algeria	5.95	0.056%
Mediteranean/Ukraine	-41.00	0.104%	East Africa	-4.84	-0.034%
Mexican Westcoast	0.46	-0.078%	East Mediteranean	-2.20	-0.016%
Northeast America	-0.48	0.086%	Caribean	1.65	0.025%
South Korea	18.11	-0.055%	Norway, Hammerfest	9.55	0.295%
South/East Africa	0.21	-0.015%	Peru	0.94	0.046%
Western Europe	-2.01	0.018%			
Total Consumer Surplus	121.90		Total Producer Surplus	-24.52	
NET WELFARE EFFECT					97.38

Appendix 12: Traded Values per Route (C-ML)

	Arabian Sea	Argentina	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Mediteranean	Western Europe	Northeast America	South Korea	Thailand	Mexican Westcoast
Alaska(Direct)	0	0	0	0	0	0	127.53	0	0	0	0	0	0
Alaska (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
Alaska (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0
Alaska (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
Alaska (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0
Alaska (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Alaska (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (Direct)	0	0	0	0	0	0	0	4731.4	332.04	0	0	0	0
Algeria (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (Suez)	385	0	0	0	185.01	0	111.24	0	0	0	40.41	0	0
Algeria (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Direct)	54.259	0	0	0	7596.4	0	10715	0	0	0	572.33	0	0
Australia (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
E. Russia (Direct)	0	0	0	0	443.38	0	5785.3	0	0	0	1578.8	0	0
E. Russia (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
E. Russia (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0
E. Russia (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
E. Russia (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0
E. Russia (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
E. Russia (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Egypt (Direct)	0	57.24	0	0	0	29.855	0	698.97	18.586	0	0	0	0
Egypt (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
Egypt (Horn)	0	0	0	0	0	0	737.8	0	0	0	0	0	0
Egypt (Hope)	0	0	0	138.56	0	0	0	0	0	0	0	0	0
Egypt (Suez)	589.32	0	0	0	864.82	0	0	0	0	0	469.61	0	0
Egypt (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Egypt (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Hammerfest (Direct)	0	167.97	193.27	0	0	99.224	0	736.95	217.39	0	0	0	0
Hammerfest (Panama)	0	0	0	38.663	0	0	0	0	0	0	0	0	0
Hammerfest (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0
Hammerfest (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
Hammerfest (Suez)	159.71	0	0	0	40.708	0	174.2	0	0	0	29.368	0	0
Hammerfest (NSR)	0	0	0	0	45.174	0	193.31	0	0	0	32.59	0	0
Hammerfest (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Direct)	0	0	0	0	13870	0	0	0	0	0	9433	0	189.71
Malay Archipelago (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabian Peninsula (Direct)	11059	0	0	0	17731	0	17400	0	0	0	13006	701.83	0
Arabian Peninsula (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabian Peninsula (Horn)	0	66.092	1577.3	183.72	0	0	0	0	0	0	0	0	0
Arabian Peninsula (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
(Arabian Peninsula Suez)	0	0	0	0	0	1445.2	0	4515.2	3512.2	152.45	0	0	0
Arabian Peninsula (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabian Peninsula (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (Direct)	0	0	0	0	0	0	529.41	0	0	0	0	363.38	0
Peru (Panama)	0	0	0	0	0	456.42	0	866.75	0	0	0	0	0
Peru (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
Trinidad (Direct)	0	2356.1	1599.2	0	0	1945.3	0	460.38	316.25	292.03	0	0	0
Trinidad (Panama)	0	0	0	1643	146.85	0	197.68	0	0	0	693.46	0	0
Trinidad (Horn)	224.04	0	0	0	0	0	0	0	0	0	0	63.052	0
Trinidad (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0
Trinidad (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0
Trinidad (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
Trinidad (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (Direct)	0	0	501.65	0	0	410.53	0	3029.1	717.86	0	0	0	0
West Africa (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (Horn)	1691.7	0	0	0	2196.3	0	5224.8	0	0	0	1591.6	79.118	0
West Africa (Hope)	0	0	0	197.5	0	0	0	0	0	0	0	0	0
West Africa (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 13: Traded Values per Route (A-ML)

	Arabian Sea	Argentina/Uruguay	Baltic	Bay of Bengal	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Malay Archipelago/SEA	Mediteranean/Ukraine	Mexican Westcoast	Northeast America	South Korea	South/East Africa	Western Europe
Gulf of Mexico (Direct)	0	1287	402	0	4467	0	0	1251	0	0	5890	0	182	5287	0	2827
Gulf of Mexico (Panama)	0	0	0	0	0	5047	1668	0	1255	1267	0	0	0	0	0	0
Gulf of Mexico (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82	0
Gulf of Mexico (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulf of Mexico (Suez)	2857	0	0	359	0	0	0	0	0	0	0	0	0	0	0	0
Gulf of Mexico (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulf of Mexico (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Direct)	493	0	0	0	0	0	27145	0	26343	0	0	0	0	1446	7	0
Australia (Panama)	0	0	0	268	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australia (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabian Archipelago (Direct)	33922	0	0	65	0	0	12282	0	6770	5526	0	0	0	5787	210	0
Arabian Archipelago (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabian Archipelago (Horn)	0	38	0	0	1041	247	0	0	0	0	0	0	0	0	0	0
Arabian Archipelago (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabian Archipelago (Suez)	0	0	173	0	0	0	0	0	0	0	3461	0	0	0	0	1771
Arabian Archipelago (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabian Archipelago (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northwest America (Direct)	0	0	0	0	0	0	1666	0	5782	0	0	251	0	0	0	0
Northwest America (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northwest America (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northwest America (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northwest America (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northwest America (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northwest America (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Direct)	0	0	0	841	0	0	22087	0	15019	8338	0	300	0	9250	528	0
Malay Archipelago (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malay Archipelago (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (Direct)	0	0	170	0	1340	0	0	223	0	0	3559	0	0	0	0	688
West Africa (Panama)	0	0	0	1662	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (Horn)	2871	0	0	0	0	0	4383	0	4563	272	0	0	0	2534	141	0
West Africa (Hope)	0	0	0	0	0	876	0	0	0	0	0	0	0	0	0	0
West Africa (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Africa (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northeast America (Direct)	0	636	225	0	1253	0	0	215	0	0	3975	0	357	0	0	1724
Northeast America (Panama)	0	0	0	0	0	729	218	0	0	0	0	0	0	0	0	0
Northeast America (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0
Northeast America (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northeast America (Suez)	0	0	0	3604	0	0	0	0	0	0	0	0	0	0	0	0
Northeast America (NSR)	0	0	0	0	0	0	0	0	494	0	0	0	0	90	0	0
Northeast America (NWP)	0	0	0	0	0	0	445	0	1007	0	0	0	0	183	0	0
Russia Kara (Direct)	0	299	991	0	0	0	0	0	0	0	0	0	0	0	0	1201
Russia Kara (Panama)	0	0	0	0	0	496	0	0	0	0	0	0	0	0	0	0
Russia Kara (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0
Russia Kara (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russia Kara (Suez)	0	0	0	2227	0	0	16	0	32	0	5968	0	0	6	0	0
Russia Kara (NSR)	0	0	0	0	0	0	764	0	1580	0	0	0	0	270	0	0
Russia Kara (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russia East (Direct)	2516	0	0	2282	0	493	2730	0	6253	0	0	0	0	2881	33	0
Russia East (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russia East (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russia East (Hope)	0	322	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Russia East (Suez)	0	0	4	0	0	0	0	0	0	0	760	0	0	0	0	9
Russia East (NSR)	0	0	202	0	0	0	0	0	0	0	0	0	0	0	0	439
Russia East (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Algeria (Direct)	0	0	64	0	0	0	0	0	0	0	7532	0	0	0	0	518
Algeria (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (Suez)	1797	0	0	120	0	0	398	0	135	0	0	0	0	50	24	0
Algeria (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algeria (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Africa (Direct)	5120	0	0	23	0	0	3564	0	1982	181	0	0	0	1412	68	0
East Africa (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Africa (Horn)	0	10	0	0	346	0	0	0	0	0	0	0	0	0	0	0
East Africa (Hope)	0	0	0	0	0	66	0	0	0	0	0	0	0	0	0	0
East Africa (Suez)	0	0	66	0	0	0	0	0	0	0	1001	0	0	0	0	534
East Africa (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Africa (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Mediteranean (Direct)	0	146	6	0	0	0	0	22	0	0	2682	0	0	0	0	48
East Mediteranean (Panama)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Mediteranean (Horn)	0	0	0	0	0	0	0	0	1468	0	0	0	0	0	0	0
East Mediteranean (Hope)	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0
East Mediteranean (Suez)	4658	0	0	95	0	0	3097	0	0	0	0	0	0	977	64	0
East Mediteranean (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
East Mediteranean (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caribean (Direct)	0	1429	30	0	1479	0	0	361	0	0	515	0	0	0	0	236
Caribean (Panama)	0	0	0	0	0	1259	154	0	117	0	0	0	0	418	0	0
Caribean (Horn)	505	0	0	0	0	0	0	0	0	82	0	0	0	0	6	0
Caribean (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caribean (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caribean (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caribean (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Norway, Hammerfest (Direct)	0	128	506	0	225	0	0	0	0	0	854	0	0	0	0	172
Norway, Hammerfest (Panama)	0	0	0	0	0	76	0	0	0	0	0	0	0	0	0	0
Norway, Hammerfest (Horn)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Norway, Hammerfest (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Norway, Hammerfest (Suez)	379	0	0	315	0	0	7	0	5	0	0	0	0	1	0	0
Norway, Hammerfest (NSR)	0	0	0	0	0	0	341	0	223	0	0	0	0	39	0	0
Norway, Hammerfest (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (Direct)	0	0	0	0	0	0	0	0	238	309	0	0	0	0	0	0
Peru (Panama)	0	0	0	0	0	0	0	75	0	0	730	0	0	0	0	0
Peru (Horn)	0	0	0	682	0	0	0	0	0	0	0	0	0	0	0	0
Peru (Hope)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (Suez)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (NSR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peru (NWP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 14: Percent Changes Traded Quantities (Climatological)

LN	Arabian Sea	Argentina	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Mediteranean	Western Europe	Northeast America	South Korea	Thailand	Mexican Westcoast
Alaska	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Algeria	-0.2	0.0	0.0	0.0	-0.3	0.0	-0.4	0.1	0.0	0.0	-0.3	0.0	0.0
Australia	0.2	0.0	0.0	0.0	0.1	0.0	-0.1	0.0	0.0	0.0	0.1	0.0	0.0
Eastern Russia	0.0	0.0	0.0	0.0	0.1	0.0	-0.1	0.0	0.0	0.0	0.1	0.0	0.0
Egypt	0.0	0.5	0.0	0.2	-0.1	0.2	-0.2	0.2	0.2	0.0	-0.1	0.0	0.0
Hammerfest, Norway	-3.9	-3.5	-3.7	-3.8	12.1	-3.8	23.9	-3.7	-3.8	0.0	20.4	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arabian Peninsula	0.1	0.5	0.3	0.3	0.0	0.2	-0.2	0.3	0.2	0.1	0.0	0.1	0.0
Peru	0.0	0.0	0.0	0.0	0.0	0.1	-0.3	0.2	0.0	0.0	0.0	-0.1	0.0
Trinidad	-0.2	0.2	0.1	0.0	-0.3	0.0	-0.4	0.0	0.0	-0.1	-0.3	-0.2	0.0
West Africa	0.0	0.0	0.3	0.2	-0.1	0.2	-0.2	0.3	0.2	0.0	-0.1	0.0	0.0
HN													
Alaska	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Algeria	-1.3	0.0	0.0	0.0	2.5	0.0	21.3	-0.3	-0.8	0.0	14.4	0.0	0.0
Australia	0.6	0.0	0.0	0.0	0.2	0.0	-0.3	0.0	0.0	0.0	0.2	0.0	0.0
Eastern Russia	0.0	0.0	0.0	0.0	0.2	0.0	-0.2	0.0	0.0	0.0	0.3	0.0	0.0
Egypt	0.1	1.5	0.0	0.7	-0.4	0.6	-0.8	1.0	0.6	0.0	-0.3	0.0	0.0
Hammerfest, Norway	-13.2	-11.8	-12.4	-12.6	57.3	-12.8	75.0	-12.3	-12.8	0.0	68.4	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arabian Peninsula	0.3	1.7	1.1	0.9	-0.2	0.7	-0.7	1.2	0.7	0.5	-0.2	0.2	0.0
Peru	0.0	0.0	0.0	0.0	0.0	0.3	-1.1	0.7	0.0	0.0	0.0	-0.3	0.0
Trinidad	-0.6	0.8	0.2	0.0	-1.0	-0.1	-1.5	0.4	-0.1	-0.3	-1.0	-0.6	0.0
West Africa	0.1	0.0	1.0	0.8	-0.3	0.6	-0.8	1.1	0.6	0.0	-0.3	0.1	0.0
NI													
Alaska	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Algeria	-1.3	0.0	0.0	0.0	2.5	0.0	21.3	-0.3	-0.8	0.0	14.4	0.0	0.0
Australia	0.6	0.0	0.0	0.0	0.2	0.0	-0.3	0.0	0.0	0.0	0.2	0.0	0.0
Eastern Russia	0.0	0.0	0.0	0.0	0.2	0.0	-0.2	0.0	0.0	0.0	0.3	0.0	0.0
Egypt	0.1	1.5	0.0	0.7	-0.4	0.6	-0.8	1.0	0.6	0.0	-0.3	0.0	0.0
Hammerfest, Norway	-13.2	-11.8	-12.4	-12.6	57.3	-12.8	75.0	-12.3	-12.8	0.0	68.4	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arabian Peninsula	0.3	1.7	1.1	0.9	-0.2	0.7	-0.7	1.2	0.7	0.5	-0.2	0.2	0.0
Peru	0.0	0.0	0.0	0.0	0.0	0.3	-1.1	0.7	0.0	0.0	0.0	-0.3	0.0
Trinidad	-0.6	0.8	0.2	0.0	-1.0	-0.1	-1.5	0.4	-0.1	-0.3	-1.0	-0.6	0.0
West Africa	0.1	0.0	1.0	0.8	-0.3	0.6	-0.8	1.1	0.6	0.0	-0.3	0.1	0.0

Appendix 15: Percent Changes Traded Quantities (Aggregated)

LN	Arabian Sea	Argentina/Uruguay	Baltic	Bay of Bengal	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Malay Archipelago/SEA	Mediteranean/Ukraine	Mexican Westcoast	Northeast America	South Korea	South/East Africa	Western Europe
Gulf of Mexico	-0.3	0.6	0.9	1.0	0.1	0.3	-0.8	0.1	-1.3	-0.5	0.9	0.0	0.7	-0.6	-0.3	0.1
Australia	0.6	0.0	0.0	2.0	0.0	0.0	0.1	0.0	-0.4	0.0	0.0	0.0	0.0	0.3	0.7	0.0
Arabian Peninsula	0.1	1.0	1.3	1.5	0.5	0.7	-0.4	0.0	-0.9	-0.1	1.3	0.0	0.0	-0.2	0.1	0.5
Northwest America	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	-0.3	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	1.8	0.0	0.0	-0.1	0.0	-0.6	0.3	0.0	-0.1	0.0	0.1	0.5	0.0
West Africa	0.0	0.0	1.2	1.3	0.4	0.6	-0.6	0.4	-1.1	-0.2	1.2	0.0	0.0	-0.4	0.0	0.3
Northeast America	0.0	-0.5	-0.3	-0.1	-1.0	-0.8	-1.1	-1.0	5.8	0.0	-0.2	0.0	-0.4	6.0	-1.4	-1.1
Russia Kara	0.0	-3.5	-3.2	-3.0	0.0	-3.8	20.2	0.0	31.3	0.0	-3.2	0.0	0.0	28.3	-4.3	-4.0
Russia East	-0.2	0.7	18.9	1.2	0.0	0.4	-0.7	0.0	-1.2	0.0	1.0	0.0	0.0	-0.5	-0.1	15.0
Algeria	-0.7	0.0	0.4	0.6	0.0	0.0	-1.3	0.0	-1.8	0.0	0.4	0.0	0.0	-1.1	-0.7	-0.4
East Africa	0.2	1.0	1.3	1.5	0.6	0.7	-0.4	0.0	-0.9	-0.1	1.3	0.0	0.0	-0.2	0.2	0.5
East Mediteranean	0.0	0.9	1.1	1.3	0.0	0.6	-0.6	0.4	-1.1	0.0	1.2	0.0	0.0	-0.4	0.0	0.3
Caribean	-0.4	0.4	0.7	0.0	0.0	0.2	-1.0	0.0	-1.5	-0.6	0.7	0.0	0.0	-0.8	-0.4	-0.1
Norway, Hammerfest	-3.1	-2.3	-2.0	-1.8	-2.7	-2.5	12.3	0.0	23.9	0.0	-2.0	0.0	0.0	20.9	-3.1	-2.8
Peru	0.0	0.0	0.0	0.7	0.0	0.0	0.0	-0.2	-1.7	-0.9	0.5	0.0	0.0	0.0	0.0	0.0
HN																
Gulf of Mexico	-1.0	2.4	3.2	-0.8	0.6	1.2	-3.2	0.5	-4.5	-1.9	2.8	0.0	3.3	-2.2	-0.9	0.0
Australia	2.3	0.0	0.0	2.5	0.0	0.0	0.1	0.0	-1.1	0.0	0.0	0.0	0.0	1.1	2.4	0.0
Arabian Peninsula	0.5	3.9	4.6	0.7	2.1	2.6	-1.8	0.0	-3.0	-0.4	4.3	0.0	0.0	-0.8	0.6	1.5
Northwest America	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	-0.8	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	2.0	0.0	0.0	-0.5	0.0	-1.7	0.9	0.0	-0.4	0.0	0.5	1.9	0.0
West Africa	0.3	0.0	4.4	0.5	1.9	2.5	-2.0	1.8	-3.2	-0.6	4.1	0.0	0.0	-1.0	0.4	1.3
Northeast America	0.0	-2.9	-2.1	-6.1	-4.7	-4.1	23.1	-4.8	31.7	0.0	-2.5	0.0	-2.0	34.7	-6.2	-5.3
Russia Kara	0.0	-12.3	-11.5	8.7	0.0	-13.5	62.7	0.0	79.2	0.0	-11.8	0.0	0.0	75.9	-15.6	-14.6
Russia East	-1.3	2.1	72.8	-1.1	0.0	0.9	-3.5	0.0	-4.8	0.0	27.9	0.0	0.0	-2.5	-1.2	65.0
Algeria	-3.1	0.0	1.1	-2.9	0.0	0.0	2.6	0.0	23.8	0.0	0.7	0.0	0.0	20.1	-3.0	-2.1
East Africa	0.6	4.0	4.8	0.8	2.2	2.8	-1.6	0.0	-2.8	-0.3	4.5	0.0	0.0	-0.6	0.7	1.7
East Mediteranean	0.0	3.4	4.2	0.2	0.0	2.2	-2.2	1.5	-3.4	0.0	3.9	0.0	0.0	-1.2	0.1	1.1
Caribean	-1.6	1.8	2.6	0.0	0.0	0.6	-3.8	-0.1	-5.1	-2.5	2.2	0.0	0.0	-2.8	-1.5	-0.6
Norway, Hammerfest	-12.3	-8.9	-8.1	6.9	-10.7	-10.1	51.3	0.0	68.5	0.0	-8.5	0.0	0.0	65.2	-12.2	-11.2
Peru	0.0	0.0	0.0	-0.7	0.0	0.0	0.0	0.6	-4.4	-1.8	2.9	0.0	0.0	0.0	0.0	0.0
NI																
Gulf of Mexico	-1.2	2.9	3.6	-0.3	0.9	1.4	-3.8	0.7	-5.3	-2.2	3.2	0.0	4.5	-2.6	-1.0	-0.3
Australia	2.7	0.0	0.0	3.6	0.0	0.0	0.1	0.0	-1.4	0.0	0.0	0.0	0.0	1.3	2.9	0.0
Arabian Peninsula	0.6	4.7	5.4	1.4	2.6	3.2	-2.1	0.0	-3.6	-0.5	5.0	0.0	0.0	-0.9	0.7	1.4
Northwest America	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	-1.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Malay Archipelago	0.0	0.0	0.0	3.0	0.0	0.0	-0.5	0.0	-2.1	1.1	0.0	-0.4	0.0	0.6	2.2	0.0
West Africa	0.3	0.0	5.1	1.2	2.4	2.9	-2.3	2.2	-3.8	-0.7	4.7	0.0	0.0	-1.1	0.5	1.2
Northeast America	0.0	-4.4	-3.7	-7.6	-6.4	-5.9	29.7	-6.6	45.5	0.0	-4.1	0.0	-2.8	47.3	-8.4	-7.6
Russia Kara	0.0	-13.5	-12.8	9.5	0.0	-15.0	70.9	0.0	88.8	0.0	-13.2	0.0	0.0	84.9	-17.5	-16.7
Russia East	-1.8	2.3	82.2	-1.0	0.0	0.8	-4.5	0.0	-6.0	0.0	34.9	0.0	0.0	-3.3	-1.7	88.0
Algeria	-3.6	0.0	1.2	-2.7	0.0	0.0	3.7	0.0	26.3	0.0	0.8	0.0	0.0	22.2	-3.4	-2.7
East Africa	0.7	4.8	5.5	1.6	2.8	3.4	-1.9	0.0	-3.4	-0.3	5.2	0.0	0.0	-0.7	0.9	1.6
East Mediteranean	0.1	4.2	4.9	0.9	0.0	2.7	-2.6	1.9	-4.1	0.0	4.5	0.0	0.0	-1.4	0.2	0.9
Caribean	-1.9	2.2	2.9	0.0	0.1	0.7	-4.6	-0.1	-6.1	-3.0	2.5	0.0	0.0	-3.4	-1.8	-1.1
Norway, Hammerfest	-14.0	-9.8	-9.1	8.2	-11.9	-11.3	58.1	0.0	76.6	0.0	-9.5	0.0	0.0	72.7	-13.8	-13.1
Peru	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.6	-5.4	-2.3	3.2	0.0	0.0	0.0	0.0	0.0

Appendix 16: Weighted Tariffs on Navigable Days (Climatological)

initial barriers	Arabian Sea	Argentina	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Mediteranean	Western Europe	Northeast America	South Korea	Thailand	Mexican Westcoast
Alaska	1.11	1.10	1.10	1.08	1.06	1.10	1.04	1.16	1.20	1.26	1.05	1.08	1.03
Algeria	1.08	1.07	1.05	1.10	1.13	1.07	1.13	1.01	1.03	1.10	1.13	1.11	1.10
Australia	1.05	1.10	1.10	1.10	1.04	1.19	1.04	1.13	1.20	1.39	1.04	1.03	1.10
Eastern Russia	1.07	1.13	1.14	1.11	1.02	1.16	1.01	1.15	1.23	1.35	1.01	1.04	1.07
Egypt	1.06	1.08	1.06	1.11	1.11	1.09	1.11	1.02	1.05	1.14	1.11	1.10	1.11
Hammerfest, Norway	1.11	1.09	1.07	1.11	1.16	1.08	1.17	1.05	1.03	1.11	1.17	1.15	1.10
Malay Archipelago	1.05	1.11	1.11	1.11	1.02	1.19	1.03	1.13	1.19	1.39	1.03	1.02	1.09
Arabian Peninsula	1.01	1.09	1.09	1.11	1.06	1.16	1.07	1.08	1.13	1.29	1.07	1.05	1.13
Peru	1.14	1.05	1.07	1.01	1.12	1.06	1.11	1.11	1.13	1.16	1.11	1.14	1.04
Trinidad	1.13	1.05	1.03	1.06	1.14	1.03	1.13	1.06	1.07	1.07	1.13	1.15	1.05
West Africa	1.09	1.05	1.04	1.08	1.12	1.09	1.13	1.06	1.08	1.15	1.13	1.11	1.10
Low Navigability													
Alaska	1.11	1.10	1.10	1.08	1.06	1.10	1.04	1.16	1.19	1.26	1.05	1.08	1.03
Algeria	1.08	1.07	1.05	1.10	1.13	1.07	1.13	1.01	1.03	1.10	1.13	1.11	1.10
Australia	1.05	1.10	1.10	1.10	1.04	1.19	1.04	1.13	1.20	1.39	1.04	1.03	1.10
Eastern Russia	1.07	1.13	1.14	1.11	1.02	1.16	1.01	1.15	1.20	1.35	1.01	1.04	1.07
Egypt	1.06	1.08	1.06	1.11	1.11	1.09	1.11	1.02	1.05	1.14	1.11	1.10	1.11
Hammerfest, Norway	1.11	1.09	1.07	1.11	1.14	1.08	1.14	1.05	1.03	1.11	1.14	1.15	1.10
Malay Archipelago	1.05	1.11	1.11	1.11	1.02	1.19	1.03	1.13	1.19	1.39	1.03	1.02	1.09
Arabian Peninsula	1.01	1.09	1.09	1.11	1.06	1.16	1.07	1.08	1.13	1.29	1.07	1.05	1.13
Peru	1.14	1.05	1.07	1.01	1.12	1.06	1.11	1.11	1.13	1.16	1.11	1.14	1.04
Trinidad	1.13	1.05	1.03	1.06	1.14	1.03	1.13	1.06	1.07	1.07	1.13	1.15	1.05
West Africa	1.09	1.05	1.04	1.08	1.12	1.09	1.13	1.06	1.08	1.15	1.13	1.11	1.10
Most Likely													
Alaska	1.11	1.10	1.10	1.08	1.06	1.10	1.04	1.15	1.17	1.26	1.05	1.08	1.03
Algeria	1.08	1.07	1.05	1.10	1.13	1.07	1.13	1.01	1.03	1.10	1.13	1.11	1.10
Australia	1.05	1.10	1.10	1.10	1.04	1.19	1.04	1.13	1.20	1.39	1.04	1.03	1.10
Eastern Russia	1.07	1.13	1.14	1.11	1.02	1.16	1.01	1.15	1.17	1.35	1.01	1.04	1.07
Egypt	1.06	1.08	1.06	1.11	1.11	1.09	1.11	1.02	1.05	1.14	1.11	1.10	1.11
Hammerfest, Norway	1.11	1.09	1.07	1.11	1.13	1.08	1.11	1.05	1.03	1.11	1.11	1.14	1.10
Malay Archipelago	1.05	1.11	1.11	1.11	1.02	1.19	1.03	1.13	1.19	1.39	1.03	1.02	1.09
Arabian Peninsula	1.01	1.09	1.09	1.11	1.06	1.16	1.07	1.08	1.13	1.29	1.07	1.05	1.13
Peru	1.14	1.05	1.07	1.01	1.12	1.06	1.11	1.11	1.13	1.16	1.11	1.14	1.04
Trinidad	1.13	1.05	1.03	1.06	1.14	1.03	1.13	1.06	1.07	1.07	1.13	1.15	1.05
West Africa	1.09	1.05	1.04	1.08	1.12	1.09	1.13	1.06	1.08	1.15	1.13	1.11	1.10
High Navigabilithy													
Alaska	1.11	1.10	1.10	1.08	1.06	1.10	1.04	1.11	1.13	1.26	1.05	1.08	1.03
Algeria	1.08	1.07	1.05	1.10	1.12	1.07	1.10	1.01	1.03	1.10	1.10	1.11	1.10
Australia	1.05	1.10	1.10	1.10	1.04	1.19	1.04	1.13	1.20	1.39	1.04	1.03	1.10
Eastern Russia	1.07	1.13	1.11	1.11	1.02	1.16	1.01	1.11	1.13	1.31	1.01	1.04	1.07
Egypt	1.06	1.08	1.06	1.11	1.11	1.09	1.11	1.02	1.05	1.14	1.11	1.10	1.11
Hammerfest, Norway	1.11	1.09	1.07	1.11	1.09	1.08	1.07	1.05	1.03	1.11	1.08	1.10	1.10
Malay Archipelago	1.05	1.11	1.11	1.11	1.02	1.19	1.03	1.13	1.19	1.39	1.03	1.02	1.09
Arabian Peninsula	1.01	1.09	1.09	1.11	1.06	1.16	1.07	1.08	1.13	1.29	1.07	1.05	1.13
Peru	1.14	1.05	1.07	1.01	1.12	1.06	1.11	1.11	1.13	1.16	1.11	1.14	1.04
Trinidad	1.13	1.05	1.03	1.06	1.14	1.03	1.13	1.06	1.07	1.07	1.13	1.15	1.05
West Africa	1.09	1.05	1.04	1.08	1.12	1.09	1.13	1.06	1.08	1.15	1.13	1.11	1.10
No Ice													
Alaska	1.11	1.10	1.10	1.08	1.06	1.10	1.04	1.09	1.06	1.07	1.05	1.08	1.03
Algeria	1.08	1.07	1.05	1.10	1.12	1.07	1.11	1.01	1.03	1.10	1.11	1.11	1.10
Australia	1.05	1.10	1.10	1.10	1.04	1.19	1.04	1.13	1.20	1.39	1.04	1.03	1.10
Eastern Russia	1.07	1.13	1.14	1.11	1.02	1.16	1.01	1.10	1.07	1.08	1.01	1.04	1.07
Egypt	1.06	1.08	1.06	1.11	1.11	1.09	1.11	1.02	1.05	1.14	1.11	1.10	1.11
Hammerfest, Norway	1.11	1.09	1.07	1.11	1.08	1.08	1.07	1.05	1.03	1.11	1.07	1.10	1.10
Malay Archipelago	1.05	1.11	1.11	1.11	1.02	1.19	1.03	1.13	1.11	1.11	1.03	1.02	1.09
Arabian Peninsula	1.01	1.09	1.09	1.11	1.06	1.16	1.07	1.08	1.13	1.29	1.07	1.05	1.13
Peru	1.14	1.05	1.07	1.01	1.12	1.06	1.11	1.11	1.13	1.16	1.11	1.14	1.04
Trinidad	1.13	1.05	1.03	1.06	1.14	1.03	1.13	1.06	1.07	1.07	1.13	1.15	1.05
West Africa	1.09	1.05	1.04	1.08	1.12	1.09	1.13	1.06	1.08	1.15	1.13	1.11	1.10

Appendix 17: Weighted Tariffs on Navigable Days (Aggregated)

	Arabian Sea	Argentina/Uruguay	Baltic	Bay of Bengal	Brazil	Chile	China/Taiwan	GoM, Carribean	Japan	Malay Archipelago/SEA	Mediteranean/Ukraine	Mexican Westcoast	Northeast America	South Korea	South/East Africa	Western Europe
Initial tariffs																
Gulf of Mexico	1.138	1.076	1.074	1.153	1.052	1.061	1.144	1.006	1.134	1.168	1.078	1.051	1.062	1.128	1.124	1.086
Australia	1.051	1.104	1.143	1.058	1.102	1.101	1.036	1.186	1.044	1.030	1.128	1.097	1.394	1.043	1.071	1.198
Arabian Peninsula	1.008	1.095	1.109	1.027	1.091	1.110	1.061	1.163	1.071	1.049	1.080	1.132	1.286	1.068	1.036	1.134
Northwest America	1.123	1.109	1.152	1.108	1.094	1.071	1.074	1.089	1.060	1.092	1.144	1.027	1.000	1.068	1.147	1.178
Malay Archipelago	1.049	1.110	1.153	1.048	1.107	1.110	1.022	1.190	1.030	1.022	1.126	1.090	1.388	1.029	1.063	1.194
West Africa	1.089	1.054	1.067	1.015	1.036	1.080	1.121	1.088	1.128	1.109	1.058	1.104	1.154	1.126	1.057	1.077
Northeast America	1.116	1.071	1.049	1.131	1.047	1.068	1.138	1.026	1.141	1.149	1.055	1.059	1.023	1.150	1.113	1.054
Russia Kara	1.114	1.098	1.032	1.135	1.074	1.116	1.173	1.092	1.178	1.160	1.144	1.042	1.133	1.176	1.131	1.040
Russia East	1.073	1.128	1.179	1.057	1.136	1.113	1.016	1.160	1.008	1.039	1.152	1.066	1.346	1.009	1.093	1.229
Algeria	1.078	1.068	1.033	1.090	1.047	1.097	1.126	1.072	1.133	1.113	1.010	1.096	1.101	1.130	1.090	1.029
East Africa	1.032	1.071	1.117	1.039	1.067	1.086	1.068	1.130	1.081	1.060	1.081	1.126	1.274	1.070	1.013	1.146
East Mediteranean	1.061	1.084	1.050	1.073	1.061	1.113	1.109	1.093	1.113	1.096	1.019	1.112	1.142	1.114	1.072	1.052
Caribean	1.125	1.052	1.064	1.127	1.028	1.058	1.143	1.015	1.127	1.146	1.058	1.055	1.065	1.132	1.096	1.071
Norway, Hammerfest	1.114	1.089	1.022	1.129	1.066	1.107	1.163	1.080	1.169	1.151	1.045	1.104	1.110	1.166	1.121	1.028
Peru	1.135	1.045	1.104	1.140	1.065	1.014	1.124	1.062	1.109	1.139	1.108	1.038	1.156	1.113	1.108	1.135
Low Navigability																
Gulf of Mexico	1.138	1.076	1.074	1.153	1.052	1.061	1.144	1.006	1.134	1.168	1.078	1.051	1.062	1.128	1.124	1.086
Australia	1.051	1.104	1.143	1.058	1.102	1.101	1.036	1.186	1.044	1.030	1.128	1.097	1.394	1.043	1.071	1.198
Arabian Peninsula	1.008	1.095	1.109	1.027	1.091	1.110	1.061	1.163	1.071	1.049	1.080	1.132	1.286	1.068	1.036	1.134
Northwest America	1.123	1.109	1.145	1.108	1.094	1.071	1.074	1.089	1.060	1.092	1.144	1.027	1.000	1.068	1.147	1.178
Malay Archipelago	1.049	1.110	1.153	1.048	1.107	1.110	1.022	1.190	1.030	1.022	1.126	1.090	1.388	1.029	1.063	1.194
West Africa	1.089	1.054	1.067	1.015	1.036	1.080	1.121	1.088	1.128	1.109	1.058	1.104	1.154	1.126	1.057	1.077
Northeast America	1.116	1.071	1.049	1.131	1.047	1.068	1.137	1.026	1.132	1.149	1.055	1.059	1.023	1.141	1.113	1.054
Russia Kara	1.114	1.098	1.032	1.135	1.074	1.116	1.144	1.092	1.135	1.150	1.144	1.042	1.133	1.137	1.131	1.040
Russia East	1.073	1.128	1.158	1.057	1.136	1.113	1.016	1.160	1.008	1.039	1.152	1.066	1.346	1.009	1.093	1.211
Algeria	1.078	1.068	1.033	1.090	1.047	1.097	1.126	1.072	1.133	1.113	1.010	1.096	1.101	1.130	1.090	1.029
East Africa	1.032	1.071	1.117	1.039	1.067	1.086	1.068	1.130	1.081	1.060	1.081	1.126	1.274	1.070	1.013	1.146
East Mediteranean	1.061	1.084	1.050	1.073	1.061	1.113	1.109	1.093	1.113	1.096	1.019	1.112	1.142	1.114	1.072	1.052
Caribean	1.125	1.052	1.064	1.127	1.028	1.058	1.143	1.015	1.127	1.146	1.058	1.055	1.065	1.132	1.096	1.071
Norway, Hammerfest	1.114	1.089	1.022	1.129	1.066	1.107	1.145	1.080	1.136	0.603	1.045	1.104	1.110	1.138	1.121	1.028
Peru	1.135	1.045	1.104	1.140	1.065	1.014	1.124	1.062	1.109	1.139	1.108	1.038	1.156	1.113	1.108	1.135
Most Likely																
Gulf of Mexico	1.138	1.076	1.074	1.153	1.052	1.061	1.144	1.006	1.134	1.168	1.078	1.051	1.062	1.128	1.124	1.086
Australia	1.051	1.104	1.143	1.058	1.102	1.101	1.036	1.186	1.044	1.030	1.128	1.097	1.394	1.043	1.071	1.198
Arabian Peninsula	1.008	1.095	1.109	1.027	1.091	1.110	1.061	1.163	1.071	1.049	1.080	1.132	1.286	1.068	1.036	1.134
Northwest America	1.123	1.109	1.136	1.108	1.094	1.071	1.074	1.089	1.060	1.092	1.144	1.027	1.000	1.068	1.147	1.178
Malay Archipelago	1.049	1.110	1.153	1.048	1.107	1.110	1.022	1.190	1.030	1.022	1.126	1.090	1.388	1.029	1.063	1.194
West Africa	1.089	1.054	1.067	1.015	1.036	1.080	1.121	1.088	1.128	1.109	1.058	1.104	1.154	1.126	1.057	1.077
Northeast America	1.116	1.071	1.049	1.131	1.047	1.068	1.137	1.026	1.124	1.149	1.055	1.059	1.023	1.134	1.113	1.054
Russia Kara	1.114	1.098	1.032	1.135	1.074	1.116	1.116	1.092	1.096	1.139	1.144	1.042	1.133	1.101	1.131	1.040
Russia East	1.073	1.128	1.137	1.057	1.136	1.113	1.016	1.160	1.008	1.039	1.152	1.066	1.346	1.009	1.093	1.191
Algeria	1.078	1.068	1.033	1.090	1.047	1.097	1.126	1.072	1.133	1.113	1.010	1.096	1.101	1.130	1.090	1.029
East Africa	1.032	1.071	1.117	1.039	1.067	1.086	1.068	1.130	1.081	1.060	1.081	1.126	1.274	1.070	1.013	1.146
East Mediteranean	1.061	1.084	1.050	1.073	1.061	1.113	1.109	1.093	1.113	1.096	1.019	1.112	1.142	1.114	1.072	1.052
Caribean	1.125	1.052	1.064	1.127	1.028	1.058	1.143	1.015	1.127	1.146	1.058	1.055	1.065	1.132	1.096	1.071
Norway, Hammerfest	1.114	1.089	1.022	1.129	1.066	1.107	1.126	1.080	1.106	1.144	1.045	1.104	1.110	1.111	1.121	1.028
Peru	1.135	1.045	1.104	1.140	1.065	1.014	1.124	1.062	1.109	1.139	1.108	1.038	1.156	1.113	1.108	1.135
High Navigability																
Gulf of Mexico	1.138	1.076	1.074	1.153	1.052	1.061	1.144	1.006	1.134	1.168	1.078	1.051	1.062	1.128	1.124	1.086
Australia	1.051	1.104	1.143	1.058	1.102	1.101	1.036	1.186	1.044	1.030	1.128	1.097	1.394	1.043	1.071	1.198
Arabian Peninsula	1.008	1.095	1.109	1.027	1.091	1.110	1.061	1.163	1.071	1.049	1.080	1.132	1.286	1.068	1.036	1.134
Northwest America	1.123	1.109	1.097	1.108	1.094	1.071	1.074	1.089	1.060	1.092	1.123	1.027	1.000	1.068	1.147	1.143
Malay Archipelago	1.049	1.110	1.153	1.048	1.107	1.110	1.022	1.190	1.030	1.022	1.126	1.090	1.388	1.029	1.063	1.194
West Africa	1.089	1.054	1.067	1.015	1.036	1.080	1.121	1.088	1.128	1.109	1.058	1.104	1.154	1.126	1.057	1.077
Northeast America	1.116	1.071	1.049	1.131	1.047	1.068	1.103	1.026	1.094	1.100	1.055	1.059	1.023	1.102	1.113	1.054
Russia Kara	1.082	1.098	1.032	1.108	1.074	1.116	1.080	1.092	1.064	1.097	1.144	1.042	1.133	1.068	1.131	1.040
Russia East	1.073	1.128	1.097	1.057	1.136	1.113	1.016	1.157	1.008	1.039	1.123	1.066	1.346	1.009	1.093	1.149
Algeria	1.078	1.068	1.033	1.090	1.047	1.097	1.117	1.072	1.099	1.113	1.010	1.096	1.101	1.103	1.090	1.029
East Africa	1.032	1.071	1.117	1.039	1.067	1.086	1.068	1.130	1.081	1.060	1.081	1.126	1.274	1.070	1.013	1.146
East Mediteranean	1.061	1.084	1.050	1.073	1.061	1.113	1.109	1.093	1.113	1.096	1.019	1.112	1.142	1.114	1.072	1.052
Caribean	1.125	1.052	1.064	1.127	1.028	1.058	1.143	1.015	1.127	1.146	1.058	1.055	1.065	1.132	1.096	1.071
Norway, Hammerfest	1.114	1.089	1.022	1.108	1.066	1.107	1.088	1.080	1.071	1.101	1.045	1.104	1.110	1.075	1.121	1.028
Peru	1.135	1.045	1.104	1.140	1.065	1.014	1.124	1.062	1.109	1.139	1.108	1.038	1.156	1.113	1.108	1.135
No Ice																
Gulf of Mexico	1.138	1.076	1.074	1.153	1.052	1.061	1.144	1.006	1.134	1.168	1.078	1.051	1.062	1.128	1.124	1.086
Australia	1.051	1.104	1.143	1.058	1.102	1.101	1.036	1.186	1.044	1.030	1.128	1.097	1.394	1.043	1.071	1.198
Arabian Peninsula	1.008	1.095	1.109	1.027	1.091	1.110	1.061	1.163	1.071	1.049	1.080	1.132	1.286	1.068	1.036	1.134
Northwest America	1.123	1.109	1.086	1.108	1.094	1.071	1.074	1.089	1.060	1.092	1.115	1.027	1.000	1.068	1.147	1.113
Malay Archipelago	1.049	1.110	1.153	1.048	1.107	1.110	1.022	1.190	1.030	1.022	1.126	1.090	1.308	1.029	1.063	1.194
West Africa	1.089	1.054	1.067	1.015	1.036	1.080	1.121	1.088	1.128	1.109	1.058	1.104	1.154	1.126	1.057	1.077
Northeast America	1.116	1.071	1.049	1.131	1.047	1.068	1.092	1.026	1.075	1.110	1.055	1.059	1.023	1.085	1.113	1.054
Russia Kara	1.073	1.098	1.032	1.106	1.074	1.116	1.068	1.092	1.050	1.090	1.144	1.042	1.133	1.055	1.131	1.040
Russia East	1.073	1.128	1.086	1.057	1.126	1.113	1.016	1.121	1.008	1.039	1.115	1.066	1.236	1.009	1.093	1.120
Algeria	1.078	1.068	1.033	1.090	1.047	1.097	1.115	1.072	1.094	1.113	1.010	1.096	1.101	1.100	1.090	1.029
East Africa	1.032	1.071	1.117	1.039	1.067	1.086	1.068	1.130	1.081	1.060	1.081	1.126	1.274	1.070	1.013	1.146
East Mediteranean	1.061	1.084	1.050	1.073	1.061	1.113	1.109	1.093	1.113	1.096	1.019	1.112	1.142	1.114	1.072	1.052
Caribean	1.125	1.052	1.064	1.127	1.028	1.058	1.143	1.015	1.127	1.146	1.058	1.055	1.065	1.132	1.096	1.071
Norway, Hammerfest	1.114	1.089	1.022	1.105	1.066	1.107	1.077	1.080	1.060	1.094	1.045	1.104	1.110	1.065	1.121	1.028
Peru	1.135	1.045	1.104	1.140	1.065	1.014	1.124	1.062	1.109	1.139	1.108	1.038	1.156	1.113	1.108	1.135

Appendix 18: Average Sailing Distances in Nautical Miles (Climatological)

Origin	Destination	DIRECT	PANAMA	HOPE	HORN	SUEZ	NSR	NWP
Alaska	Arabian Sea	9613	########	######	######	######	######	######
	Argentina	######	11222	######	9024	######	######	######
	Brazil	######	8324	######	######	######	######	######
	Chile	7406	########	######	######	######	######	######
	China/Taiwan	4750	########	######	######	######	######	######
	GoM, Carribean	######	5736	######	######	######	######	######
	Japan	3849	########	######	######	######	######	######
	Mediteranean	######	10831	######	######	######	8344	8589
	Western Europe	######	10351	######	######	######	6484	7540
	Northeast America	######	7674	######	######	######	8672	6826
	South Korea	4175	########	######	######	######	######	######
	Thailand	6664	########	######	######	######	######	######
	Mexican Westcoast	2987	########	######	######	######	######	######
Algeria	Arabian Sea	######	########	10802	######	4718	######	######
	Argentina	6227	########	######	######	######	######	######
	Brazil	4241	########	######	######	######	######	######
	Chile	######	7744	######	8778	######	######	######
	China/Taiwan	######	########	13347	######	8585	10286	12900
	GoM, Carribean	4935	########	######	######	######	######	######
	Japan	######	########	14299	######	9537	8954	9478
	Mediteranean	779	########	######	######	######	######	######
	Western Europe	1719	########	######	######	######	######	######
	Northeast America	3534	########	######	######	######	######	######
	South Korea	######	########	14074	######	9312	9404	12500
	Thailand	######	########	12290	######	7528	11500	12600
	Mexican Westcoast	######	7479	######	######	######	######	######
Australia	Arabian Sea	4370	########	######	######	######	######	######
	Argentina	######	########	9439	9677	######	######	######
	Brazil	######	########	9285	11522	12155	######	######
	Chile	9152	########	######	######	######	######	######
	China/Taiwan	3011	########	######	######	######	######	######
	GoM, Carribean	######	12032	12708	######	13296	######	######
	Japan	3777	########	######	######	######	######	######
	Mediteranean	######	########	11728	######	7982	######	######
	Western Europe	######	########	11767	######	9608	######	######
	Northeast America	######	########	######	######	11505	######	######
	South Korea	3721	########	######	######	######	######	######
	Thailand	2500	########	######	######	######	######	######
	Mexican Westcoast	8795	########	######	######	######	######	######
Eastern Russia	Arabian Sea	6190	########	######	######	######	######	######
	Argentina	######	########	12704	11643	######	######	######
	Brazil	######	12060	12382	######	######	10991	11531
	Chile	10252	########	######	######	######	######	######
	China/Taiwan	1356	########	######	######	######	######	######
	GoM, Carribean	######	9643	######	######	######	######	######
	Japan	694	########	######	######	######	######	######
	Mediteranean	######	########	######	######	9818	8545	9417
	Western Europe	######	########	######	######	11444	6685	9012
	Northeast America	######	10672	######	######	######	8873	8290
	South Korea	752	########	######	######	######	######	######
	Thailand	3241	########	######	######	######	######	######
	Mexican Westcoast	5984	########	######	######	######	######	######
Egypt	Arabian Sea	######	########	12205	######	3294	######	######
	Argentina	7664	########	######	######	######	######	######
	Brazil	5531	########	######	######	######	######	######
	Chile	######	9181	######	10215	######	######	######
	China/Taiwan	######	########	14785	######	7166	######	######
	GoM, Carribean	6372	########	######	######	######	10500	8314
	Japan	######	########	9736	######	8117	######	######
	Mediteranean	1452	########	######	######	######	######	######
	Western Europe	3074	########	######	######	######	######	######
	Northeast America	4971	########	######	######	######	######	######
	South Korea	######	########	15531	######	7912	######	######
	Thailand	######	########	13727	######	6108	######	######
	Mexican Westcoast	######	8916	######	######	######	######	######
Hammerfest, No	Arabian Sea	######	########	12738	######	7810	11300	######
	Argentina	8133	########	######	######	######	######	######
	Brazil	5974	########	######	######	######	######	######
	Chile	######	8474	######	10688	######	######	######
	China/Taiwan	######	########	######	######	11681	7159	10348
	GoM, Carribean	5488	########	######	######	######	######	######
	Japan	######	########	######	######	12633	5827.0	9419
	Mediteranean	3528	########	######	######	######	######	######
	Western Europe	1668	########	######	######	######	######	######
	Northeast America	3856	########	######	######	######	######	######
	South Korea	######	########	######	######	12408	6277	9744
	Thailand	######	########	######	######	10624	8500	######
	Mexican Westcoast	######	8209	######	######	######	######	######

Malay Archipelag	Arabian Sea	4143	########	######	######	######	######	######
	Argentina	######	########	10044	10408	######	######	######
	Brazil	######	########	9722	######	11854	######	######
	Chile	9883	########	######	######	######	######	######
	China/Taiwan	1851	########	######	######	######	######	######
	GoM, Carribean	######	11665	######	######	12569	######	######
	Japan	2608	########	######	######	######	######	######
	Mediteranean	######	########	12333	######	7771	######	######
	Western Europe	######	########	######	######	9398	10232	######
	Northeast America	######	########	######	######	11294	12420	10812
	South Korea	2489	########	######	######	######	######	######
	Thailand	1780	########	######	######	######	######	######
	Mexican Westcoast	8112	########	######	######	######	######	######
Arabian Peninsul	Arabian Sea	703	########	######	######	######	######	######
	Argentina	######	########	8637	######	10432	######	######
	Brazil	######	########	8315	######	8298	######	######
	Chile	######	########	9931	######	11949	######	######
	China/Taiwan	5039	########	######	######	######	######	######
	GoM, Carribean	######	########	11955	######	9140	######	######
	Japan	6074	########	######	######	######	######	######
	Mediteranean	######	########	10925	######	4216	######	######
	Western Europe	######	########	10964	######	5842	######	######
	Northeast America	######	########	11791	######	7738	######	######
	South Korea	5850	########	######	######	######	######	######
	Thailand	4065	########	######	######	######	######	######
	Mexican Westcoast	11944	########	######	######	######	######	######
Peru	Arabian Sea	######	########	######	11529	11372	######	######
	Argentina	######	7511	######	4101	######	######	######
	Brazil	######	5352	######	5947	######	######	######
	Chile	1256	########	######	######	######	######	######
	China/Taiwan	10285	########	######	######	######	######	######
	GoM, Carribean	######	2934	######	10018	######	######	######
	Japan	9362	########	######	######	######	######	######
	Mediteranean	######	7071	######	10402	######	######	######
	Western Europe	######	6605	######	10439	######	######	######
	Northeast America	######	3963	######	10224	######	######	######
	South Korea	9749	########	######	######	######	######	######
	Thailand	11568	########	######	######	######	######	######
	Mexican Westcoast	3440	########	######	######	######	######	######
Trinidad	Arabian Sea	######	########	10670	######	8771	######	######
	Argentina	4699	########	######	######	######	######	######
	Brazil	2540	########	######	######	######	######	######
	Chile	######	4005	######	7267	######	######	######
	China/Taiwan	######	10679	######	######	######	######	######
	GoM, Carribean	1715	########	######	######	######	######	######
	Japan	######	9715	######	######	######	######	######
	Mediteranean	4501	########	######	######	######	######	######
	Western Europe	4179	########	######	######	######	######	######
	Northeast America	2297	########	######	######	######	######	######
	South Korea	######	10102	######	######	######	######	######
	Thailand	######	########	12191	######	11585	######	######
	Mexican Westcoast	######	3740	######	######	######	######	######
West Africa	Arabian Sea	######	########	7612	######	8758	######	######
	Argentina	4945	########	######	######	######	######	######
	Brazil	3256	########	######	######	######	######	######
	Chile	######	8432	######	7187	######	######	######
	China/Taiwan	######	########	10071	######	12861	######	######
	GoM, Carribean	6035	########	######	######	######	######	######
	Japan	######	########	11018	######	######	######	######
	Mediteranean	4504	########	######	######	######	######	######
	Western Europe	4542	########	######	######	######	######	######
	Northeast America	5377	########	######	######	######	######	######
	South Korea	######	########	10798	######	######	######	######
	Thailand	######	########	9062	######	11560	######	######
	Mexican Westcoast	######	8167	######	11363	######	######	######

Appendix 19: Average Sailing Distances in Nautical Miles (Aggregated)

Origin	Destination	DIRECT	PANAMA	HOPE	HORN	SUEZ	NSR	NWP
Gulf of Mexico	Arabian Sea	########	#######	12765	########	9879	#######	#######
	Argentina/Uruguay	6942	#######	#######	########	#######	#######	#######
	Baltic	5919	#######	#######	########	#######	#######	#######
	Bay of Bengal	########	#######	13123	########	11144	#######	#######
	Brazil	4783	#######	#######	########	#######	#######	#######
	Chile	########	4315	#######	9510	#######	#######	#######
	China/Taiwan	########	10767	#######	########	#######	#######	#######
	GoM, Carribean	400	#######	#######	########	#######	#######	#######
	Japan	########	10269	#######	########	#######	#######	#######
	Malay Archipelago/SEA	########	12767	#######	########	12923	#######	#######
	Mediteranean/Ukraine	6080	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	3431	#######	########	#######	#######	#######
	Northeast America	2184	#######	#######	########	#######	#######	#######
	South Korea	11024	#######	#######	########	#######	#######	#######
	South/East Africa	########	#######	9925	########	10638	#######	#######
	Western Europe	5127	#######	#######	########	#######	#######	#######
Australia	Arabian Sea	4370	#######	#######	########	#######	#######	#######
	Argentina/Uruguay	########	#######	9439	9677	#######	#######	#######
	Baltic	11489	#######	#######	########	#######	#######	#######
	Bay of Bengal	########	3737	#######	########	#######	#######	#######
	Brazil	########	#######	9285	11522	12155	#######	#######
	Chile	9152	#######	#######	########	#######	#######	#######
	China/Taiwan	3011	#######	#######	########	#######	#######	#######
	GoM, Carribean	########	12032	12708	########	13296	#######	#######
	Japan	3777	#######	#######	########	#######	#######	#######
	Malay Archipelago/SEA	2500	#######	#######	########	#######	#######	#######
	Mediteranean/Ukraine	########	#######	11728	########	7982	#######	#######
	Mexican Westcoast	8795	#######	#######	########	#######	#######	#######
	Northeast America	########	#######	#######	########	11505	#######	#######
	South Korea	3721	#######	#######	########	#######	#######	#######
	South/East Africa	5720	#######	#######	########	#######	#######	#######
	Western Europe	########	#######	11767	########	9608	#######	#######
Arabian Peninsula	Arabian Sea	703	#######	#######	########	#######	#######	#######
	Argentina/Uruguay	########	#######	8637	########	10432	#######	#######
	Baltic	########	#######	11943	########	6822	#######	#######
	Bay of Bengal	2267	#######	#######	########	#######	#######	#######
	Brazil	########	#######	8315	########	8298	#######	#######
	Chile	########	#######	9931	########	11949	#######	#######
	China/Taiwan	5039	#######	#######	########	#######	#######	#######
	GoM, Carribean	########	#######	11955	########	9140	#######	#######
	Japan	6074	#######	#######	########	#######	#######	#######
	Malay Archipelago/SEA	4065	#######	#######	########	#######	#######	#######
	Mediteranean/Ukraine	########	#######	10925	########	4216	#######	#######
	Mexican Westcoast	11944	#######	#######	########	#######	#######	#######
	Northeast America	########	#######	11791	########	7738	#######	#######
	South Korea	5850	#######	#######	########	#######	#######	#######
	South/East Africa	2838	#######	#######	########	#######	#######	#######
	Western Europe	########	#######	10964	########	5842	#######	#######
Northwest America	Arabian Sea	10506	#######	#######	########	#######	#######	#######
	Argentina/Uruguay	########	10252	#######	########	8054	#######	#######
	Baltic	########	10960	#######	########	#######	7588	9133
	Bay of Bengal	9217	#######	#######	########	#######	#######	#######
	Brazil	########	7354	#######	########	#######	#######	#######
	Chile	6436	#######	#######	########	#######	#######	#######
	China/Taiwan	6207	#######	#######	########	#######	#######	#######
	GoM, Carribean	########	4766	#######	########	#######	#######	#######
	Japan	5130	#######	#######	########	#######	#######	#######
	Malay Archipelago/SEA	7627	#######	#######	########	#######	#######	#######
	Mediteranean/Ukraine	########	9936	#######	########	#######	9612	9805
	Mexican Westcoast	2446	#######	#######	########	#######	#######	#######
	Northeast America		6506	#######	########	#######	#######	6210
	South Korea	5839	#######	#######	########	#######	#######	#######
	South/East Africa	11827	#######	#######	########	#######	#######	#######
	Western Europe	########	9183	#######	########	#######	7379	8458

Malay Archipelago	Arabian Sea	4143	#######	#######	########	#######	#######	#######
	Argentina/Uruguay	########	#######	10044	10408	#######	#######	#######
	Baltic	########	#######	#######	########	10377	#######	#######
	Bay of Bengal	4072	#######	#######	########	#######	#######	#######
	Brazil	########	#######	9722	########	11854	#######	#######
	Chile	9883	#######	#######	########	#######	#######	#######
	China/Taiwan	1851	#######	#######	########	#######	#######	#######
	GoM, Carribean	########	11665	#######	########	12569	#######	#######
	Japan	2608	#######	#######	########	#######	#######	#######
	Malay Archipelago/SEA	1780	#######	#######	########	#######	#######	#######
	Mediteranean/Ukraine	########	#######	12333	########	7771	#######	#######
	Mexican Westcoast	8112	#######	#######	########	#######	#######	#######
	Northeast America	########	#######	#######	########	11294	#######	10812
	South Korea	2489	#######	#######	########	#######	#######	#######
	South/East Africa	5051	#######	#######	########	#######	#######	#######
	Western Europe	########	#######	#######	########	9398	#######	#######
West Africa	Arabian Sea	########	#######	7612	########	8758	#######	#######
	Argentina/Uruguay	4945	#######	#######	########	#######	#######	#######
	Baltic	5367	#######	#######	########	#######	#######	#######
	Bay of Bengal	########		7418	########	8360	#######	#######
	Brazil	3256	#######	#######	########	#######	#######	#######
	Chile	########	8432	#######	7187	#######	#######	#######
	China/Taiwan	########	#######	10071	########	12861	#######	#######
	GoM, Carribean	6035	#######	#######	########	#######	#######	#######
	Japan	########	#######	11018	########	#######	#######	#######
	Malay Archipelago/SEA	########	#######	9062	########	11560	#######	#######
	Mediteranean/Ukraine	4504	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	8167	#######	11363	#######	#######	#######
	Northeast America	5377	#######	#######	########	#######	#######	#######
	South Korea	########	#######	10798	########	#######	#######	#######
	South/East Africa	########	#######	4578	########	#######	#######	#######
	Western Europe	4542	#######	#######	########	#######	#######	#######
Northeast America	Arabian Sea	########	#######	11961	########	8036	#######	#######
	Argentina/Uruguay	6480	#######	#######	########	#######	#######	#######
	Baltic	3964	#######	#######	########	#######	#######	#######
	Bay of Bengal	########	#######	12319	########	9302	#######	#######
	Brazil	4320	#######	#######	########	#######	#######	#######
	Chile	########	4969	#######	9047	#######	#######	#######
	China/Taiwan	########	10300	#######	########	11752	11333	7700
	GoM, Carribean	1749	#######	#######	########	#######	#######	#######
	Japan	########	10923	#######	########	12500	9733	6500
	Malay Archipelago/SEA	########	11200	#######	########	11081	11933	9200
	Mediteranean/Ukraine	4238	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	4085	#######	########	#######	#######	#######
	Northeast America	800	#######	#######	########	#######	#######	#######
	South Korea	########	11679	#######	########	#######	9733	7300
	South/East Africa	########	#######	9121	########	8795	#######	#######
	Western Europe	3174	#######	#######	########	#######	#######	#######
Russia Kara	Arabian Sea	########	#######	#######	########	7810	6915	#######
	Argentina/Uruguay	8943	#######	#######	########	#######	#######	#######
	Baltic	2567	#######	#######	########	#######	#######	#######
	Bay of Bengal	1E+200	#######	#######	########	9655	9763	#######
	Brazil	6784	#######	#######	########	#######	#######	#######
	Chile	########	9284	#######	10688	#######	#######	#######
	China/Taiwan	########	#######	#######	########	12491	6349	#######
	GoM, Carribean	6298	#######	#######	########	#######	#######	#######
	Japan	########	#######	#######	########	13443	5017	#######
	Malay Archipelago/SEA	########	#######	#######	########	11434	8173	#######
	Mediteranean/Ukraine	3781	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	8400	#######	########	#######	7333	#######
	Northeast America	4666	#######	#######	########	#######	#######	#######
	South Korea	########	#######	#######	########	13218	5467	#######
	South/East Africa	1E+200	#######	10560	########	9149	#######	#######
	Western Europe	2358	#######	#######	########	#######	#######	#######
Russia East	Arabian Sea	6190	#######	#######	########	#######	#######	#######
	Argentina/Uruguay	########	#######	12704	11643	#######	#######	#######
	Baltic	########	#######	#######	########	12424	7584	9582
	Bay of Bengal	4831	#######	#######	########	#######	#######	#######
	Brazil	########	12060	12382	########	#######	#######	11531
	Chile	10252	#######	#######	########	#######	#######	#######
	China/Taiwan	1356	#######	#######	########	#######	#######	#######
	GoM, Carribean	########	9643	#######	########	#######	10500	8314
	Japan	694	#######	#######	########	#######	#######	#######
	Malay Archipelago/SEA	3241	#######	#######	########	#######	#######	#######
	Mediteranean/Ukraine	########	#######	#######	########	9818	9608	9417
	Mexican Westcoast	5984	#######	#######	########	#######	#######	#######
	Northeast America	########	10672	#######	########	#######	10845	8290
	South Korea	752	#######	#######	########	#######	#######	#######
	South/East Africa	7440	#######	#######	########	#######	#######	#######
	Western Europe	########	#######	#######	########	11444	7795	9012

Algeria	Arabian Sea	########	#######	10802	########	4718	#######	#######
	Argentina/Uruguay	6227	#######	#######	########	#######	#######	#######
	Baltic	2617	#######	#######	########	#######	#######	#######
	Bay of Bengal	########	#######	10979	########	5749	#######	#######
	Brazil	4241	#######	#######	########	#######	#######	#######
	Chile	########	7744	#######	8778	#######	#######	#######
	China/Taiwan	########	#######	13347	########	8585	10286	10700
	GoM, Carribean	4935	#######	#######	########	#######	#######	#######
	Japan	########	#######	14299	########	9537	8827	9478
	Malay Archipelago/SEA	########	#######	12290	########	7528	11527	12600
	Mediteranean/Ukraine	779	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	7479	#######	########	#######	#######	#######
	Northeast America	3534	#######	#######	########	#######	#######	#######
	South Korea	########	#######	14074	########	9312	9277	10300
	South/East Africa	########	#######	7781	########	5243	#######	#######
	Western Europe	1719	#######	#######	########	#######	#######	#######
East Africa	Arabian Sea	2683	#######	#######	########	#######	#######	#######
	Argentina/Uruguay	########	#######	6424	########	11074	#######	#######
	Baltic	########	#######	9731	########	7463	#######	#######
	Bay of Bengal	3345	#######	#######	########	#######	#######	#######
	Brazil	########	#######	6102	########	9840	#######	#######
	Chile	########	#######	#######	7718	#######	#######	#######
	China/Taiwan	5685	#######	#######	########	#######	#######	#######
	GoM, Carribean	########	#######	8851	########	9151	#######	#######
	Japan	6943	#######	#######	########	#######	#######	#######
	Malay Archipelago/SEA	5014	#######	#######	########	#######	#######	#######
	Mediteranean/Ukraine	########	#######	#######	########	4333	#######	#######
	Mexican Westcoast	########	11183	#######	11341	#######	#######	#######
	Northeast America	########	#######	9612	########	8430	#######	#######
	South Korea	5977	#######	#######	########	#######	#######	#######
	South/East Africa	1000	#######	#######	########	#######	#######	#######
	Western Europe	########	#######	8772	########	6505	#######	#######
East Mediteranean	Arabian Sea	########	#######	12205	########	3294	#######	#######
	Argentina/Uruguay	7664	#######	#######	########	#######	#######	#######
	Baltic	4031	#######	#######	########	#######	#######	#######
	Bay of Bengal	########	#######	12393	########	4355	#######	#######
	Brazil	5531	#######	#######	########	#######	#######	#######
	Chile	########	9181	#######	10215	#######	#######	#######
	China/Taiwan	########	#######	14785	########	7166	#######	#######
	GoM, Carribean	6372	#######	#######	########	#######	#######	#######
	Japan	########	#######	9736	########	8117	#######	#######
	Malay Archipelago/SEA	########	#######	13727	########	6108	#######	#######
	Mediteranean/Ukraine	1452	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	8916	#######	########	#######	#######	#######
	Northeast America	4971	#######	#######	########	#######	#######	#######
	South Korea	########	#######	15531	########	7912	#######	#######
	South/East Africa	########	#######	9195	########	3848	#######	#######
	Western Europe	3074	#######	#######	########	#######	#######	#######
Caribean	Arabian Sea	########	#######	10670	########	8771	#######	#######
	Argentina/Uruguay	4699	#######	#######	########	#######	#######	#######
	Baltic	5150	#######	#######	########	#######	#######	#######
	Bay of Bengal	########	#######	10880	########	9806	#######	#######
	Brazil	2540	#######	#######	########	#######	#######	#######
	Chile	########	4005	#######	7267	#######	#######	#######
	China/Taiwan	########	10679	#######	########	#######	#######	#######
	GoM, Carribean	1000	#######	#######	########	#######	#######	#######
	Japan	########	9715	#######	########	#######	#######	#######
	Malay Archipelago/SEA	########	#######	12191	########	11585	#######	#######
	Mediteranean/Ukraine	4501	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	3740	#######	########	#######	#######	#######
	Northeast America	2297	#######	#######	########	#######	#######	#######
	South Korea	########	10102	#######	########	#######	#######	#######
	South/East Africa	########	#######	7682	########	9299	#######	#######
	Western Europe	4179	#######	#######	########	#######	#######	#######
Norway, Hammerfest	Arabian Sea	########	#######	#######	########	7810	11300	#######
	Argentina/Uruguay	8133	#######	#######	########	#######	#######	#######
	Baltic	1757	#######	#######	########	#######	#######	#######
	Bay of Bengal	########	#######	12948	########	9110	9700	#######
	Brazil	5974	#######	#######	########	#######	#######	#######
	Chile	########	8474	#######	10688	#######	#######	#######
	China/Taiwan	########	#######	#######	########	11681	7159	10348
	GoM, Carribean	5488	#######	#######	########	#######	#######	#######
	Japan	########	#######	#######	########	12633	5827	9419
	Malay Archipelago/SEA	########	#######	#######	########	10624	8527	#######
	Mediteranean/Ukraine	3528	#######	#######	########	#######	#######	#######
	Mexican Westcoast	########	8209	#######	########	#######	#######	#######
	Northeast America	3856	#######	#######	########	#######	#######	#######
	South Korea	########	#######	#######	########	12408	6277	9744
	South/East Africa	########	#######	9750	########	8339	#######	#######
	Western Europe	1668	#######	#######	########	#######	#######	#######
Peru	Arabian Sea	########	#######	#######	11529	11372	#######	#######
	Argentina/Uruguay	########	7511	#######	4101	#######	#######	#######
	Baltic	########	7050	#######	11720	#######	#######	#######
	Bay of Bengal	########	#######	11909	########	11981	#######	#######
	Brazil	########	5352	#######	5947	#######	#######	#######
	Chile	1256	#######	#######	########	#######	#######	#######
	China/Taiwan	10285	#######	#######	########	#######	#######	#######
	GoM, Carribean	########	2934	#######	10018	#######	#######	#######
	Japan	9362	#######	#######	########	#######	#######	#######
	Malay Archipelago/SEA	11568	#######	#######	########	#######	#######	#######
	Mediteranean/Ukraine	########	7071	#######	10402	#######	#######	#######
	Mexican Westcoast	3440	#######	#######	########	#######	#######	#######
	Northeast America	########	3963	#######	10224	#######	#######	#######
	South Korea	9749	#######	#######	########	#######	#######	#######
	South/East Africa	########	10095	#######	8711	#######	#######	#######
	Western Europe	########	6605	#######	10439	#######	#######	#######

Appendix 20: Average Days at Sea (Climatological)

Origin	Destination	DIRECT	PAN	HOPE	HORN	SUEZ	NSR	TPP	NSR 3	NWP	TPP NI	NWP NI
Alaska	Arabian Sea	21.1	#####	######	#####	#####	####	####	#####	####	######	######
	Argentina	######	25.5	######	19.8	#####	####	####	#####	####	######	######
	Brazil	######	19.2	######	#####	#####	####	####	#####	####	######	######
	Chile	16.2	#####	######	#####	#####	####	####	#####	####	######	######
	China/Taiwan	10.4	#####	######	#####	#####	####	####	#####	####	######	######
	GoM, Carribean	######	13.5	######	#####	#####	####	####	#####	####	######	######
	Japan	8.4	#####	######	#####	#####	####	####	#####	####	######	######
	Mediteranean	######	24.7	######	#####	#####	21.4	20.6	20.9	21.3	16.8	18.8
	Western Europe	######	23.6	######	#####	#####	17.3	16.5	16.8	19.0	12.7	16.5
	Northeast America	######	17.7	######	#####	#####	22.1	21.3	21.6	17.5	17.5	15.0
	South Korea	9.2	#####	######	#####	#####	####	####	#####	####	######	######
	Thailand	14.6	#####	######	#####	#####	####	####	#####	####	######	######
	Mexican Westcoast	6.5	#####	######	#####	#####	####	####	#####	####	######	######
Algeria	Arabian Sea	######	#####	23.7	#####	11.7	####	####	#####	####	######	######
	Argentina	13.7	#####	######	#####	#####	####	####	#####	####	######	######
	Brazil	9.3	#####	######	#####	#####	####	####	#####	####	######	######
	Chile	######	17.9	######	19.3	#####	####	####	#####	####	######	######
	China/Taiwan	######	#####	29.3	#####	20.1	25.6	24.8	25.2	30.8	21.0	28.3
	GoM, Carribean	10.8	#####	######	#####	#####	####	####	#####	####	######	######
	Japan	######	#####	31.4	#####	22.2	22.7	21.9	22.3	23.3	18.1	20.8
	Mediteranean	1.7	#####	######	#####	#####	####	####	#####	####	######	######
	Western Europe	3.8	#####	######	#####	#####	####	####	#####	####	######	######
	Northeast America	7.7	#####	######	#####	#####	####	####	#####	####	######	######
	South Korea	######	#####	30.9	#####	21.7	23.7	22.9	23.2	29.9	19.1	27.4
	Thailand	######	#####	27.0	#####	17.8	28.3	27.5	27.8	30.1	23.7	27.6
	Mexican Westcoast	######	17.3	######	#####	#####	####	####	#####	####	######	######
Australia	Arabian Sea	9.6	#####	######	#####	#####	####	####	#####	####	######	######
	Argentina	######	#####	20.7	21.2	#####	####	####	#####	####	######	######
	Brazil	######	#####	20.4	25.3	28.0	####	####	#####	####	######	######
	Chile	20.1	#####	######	#####	#####	####	####	#####	####	######	######
	China/Taiwan	6.6	#####	######	#####	#####	####	####	#####	####	######	######
	GoM, Carribean	######	27.3	27.9	#####	30.5	####	####	#####	####	######	######
	Japan	8.3	#####	######	#####	#####	####	####	#####	####	######	######
	Mediteranean	######	#####	25.7	#####	18.8	####	####	#####	####	######	######
	Western Europe	######	#####	25.8	#####	22.4	####	####	#####	####	######	######
	Northeast America	######	#####	######	#####	26.5	####	####	#####	####	######	######
	South Korea	8.2	#####	######	#####	#####	####	####	#####	####	######	######
	Thailand	5.5	#####	######	#####	#####	####	####	#####	####	######	######
	Mexican Westcoast	19.3	#####	######	#####	#####	####	####	#####	####	######	######
Eastern Russia	Arabian Sea	13.6	#####	######	#####	#####	####	####	#####	####	######	######
	Argentina	######	#####	27.9	25.5	#####	####	####	#####	####	######	######
	Brazil	######	27.4	27.2	#####	#####	27.2	26.4	26.7	27.8	22.6	25.3
	Chile	22.5	#####	######	#####	#####	####	####	#####	####	######	######
	China/Taiwan	3.0	#####	######	#####	#####	####	####	#####	####	######	######
	GoM, Carribean	######	22.1	######	#####	#####	####	####	#####	####	######	######
	Japan	1.5	#####	######	#####	#####	####	####	#####	####	######	######
	Mediteranean	######	#####	######	#####	22.8	21.8	21.0	21.4	23.2	17.2	20.7
	Western Europe	######	#####	######	#####	26.4	17.7	16.9	17.3	22.3	13.1	19.8
	Northeast America	######	24.3	######	#####	#####	22.5	21.7	22.1	20.7	17.9	18.2
	South Korea	1.6	#####	######	#####	#####	####	####	#####	####	######	######
	Thailand	7.1	#####	######	#####	#####	####	####	#####	####	######	######
	Mexican Westcoast	13.1	#####	######	#####	#####	####	####	#####	####	######	######
Egypt	Arabian Sea	######	#####	26.8	#####	8.5	####	####	#####	####	######	######
	Argentina	16.8	#####	######	#####	#####	####	####	#####	####	######	######
	Brazil	12.1	#####	######	#####	#####	####	####	#####	####	######	######
	Chile	######	21.0	######	22.4	#####	####	####	#####	####	######	######
	China/Taiwan	######	#####	32.4	#####	17.0	####	####	#####	####	######	######
	GoM, Carribean	14.0	#####	######	#####	#####	26.1	25.3	25.7	20.7	21.5	18.2
	Japan	######	#####	21.4	#####	19.1	####	####	#####	####	######	######
	Mediteranean	3.2	#####	######	#####	#####	####	####	#####	####	######	######
	Western Europe	6.7	#####	######	#####	#####	####	####	#####	####	######	######
	Northeast America	10.9	#####	######	#####	#####	####	####	#####	####	######	######
	South Korea	######	#####	34.1	#####	18.7	####	####	#####	####	######	######
	Thailand	######	#####	30.1	#####	14.7	####	####	#####	####	######	######
	Mexican Westcoast	######	20.5	######	#####	#####	####	####	#####	####	######	######
Hammerfest, Norway	Arabian Sea	######	#####	27.9	#####	18.4	27.9	27.1	27.4	####	23.2	######
	Argentina	17.8	#####	######	#####	#####	####	####	#####	####	######	######
	Brazil	13.1	#####	######	#####	#####	####	####	#####	####	######	######
	Chile	######	19.5	######	23.4	#####	####	####	#####	####	######	######
	China/Taiwan	######	#####	######	#####	26.9	18.8	18.0	18.3	25.2	14.2	22.7
	GoM, Carribean	12.0	#####	######	#####	#####	####	####	#####	####	######	######
	Japan	######	#####	######	#####	29.0	15.9	15.1	15.4	23.2	11.2	20.7
	Mediteranean	7.7	#####	######	#####	#####	####	####	#####	####	######	######
	Western Europe	3.7	#####	######	#####	#####	####	####	#####	####	######	######
	Northeast America	8.5	#####	######	#####	#####	####	####	#####	####	######	######
	South Korea	######	#####	######	#####	28.5	16.8	16.0	16.4	23.9	12.2	21.4
	Thailand	######	#####	######	#####	24.6	21.7	20.9	21.3	####	17.1	######
	Mexican Westcoast	######	18.9	######	#####	#####	####	####	#####	####	######	######

Malay Archipelago	Arabian Sea	9.1	#####	######	#####	#####	####	####	#####	####	######	######
	Argentina	######	#####	22.0	22.8	#####	####	####	#####	####	######	######
	Brazil	######	#####	21.3	#####	27.3	####	####	#####	####	######	######
	Chile	21.7	#####	######	#####	#####	####	####	#####	####	######	######
	China/Taiwan	4.1	#####	######	#####	#####	####	####	#####	####	######	######
	GoM, Carribean	######	26.5	######	#####	28.9	####	####	#####	####	######	######
	Japan	5.7	#####	######	#####	#####	####	####	#####	####	######	######
	Mediteranean	######	#####	27.0	#####	18.4	####	####	#####	####	######	######
	Western Europe	######	#####	######	#####	21.9	25.5	24.7	25.1	####	20.9	######
	Northeast America	######	#####	######	#####	26.1	30.3	29.5	29.9	26.2	25.7	23.7
	South Korea	5.5	#####	######	#####	#####	####	####	#####	####	######	######
	Thailand	3.9	#####	######	#####	#####	####	####	#####	####	######	######
	Mexican Westcoast	17.8	#####	######	#####	#####	####	####	#####	####	######	######
Arabian Peninsula	Arabian Sea	1.5	#####	######	#####	#####	####	####	#####	####	######	######
	Argentina	######	#####	18.9	#####	24.2	####	####	#####	####	######	######
	Brazil	######	#####	18.2	#####	19.5	####	####	#####	####	######	######
	Chile	######	#####	21.8	#####	27.5	####	####	#####	####	######	######
	China/Taiwan	11.1	#####	######	#####	#####	####	####	#####	####	######	######
	GoM, Carribean	######	#####	26.2	#####	21.4	####	####	#####	####	######	######
	Japan	13.3	#####	######	#####	#####	####	####	#####	####	######	######
	Mediteranean	######	#####	24.0	#####	10.6	####	####	#####	####	######	######
	Western Europe	######	#####	24.0	#####	14.1	####	####	#####	####	######	######
	Northeast America	######	#####	25.9	#####	18.3	####	####	#####	####	######	######
	South Korea	12.8	#####	######	#####	#####	####	####	#####	####	######	######
	Thailand	8.9	#####	######	#####	#####	####	####	#####	####	######	######
	Mexican Westcoast	26.2	#####	######	#####	#####	####	####	#####	####	######	######
Peru	Arabian Sea	######	#####	######	25.3	26.2	####	####	#####	####	######	######
	Argentina	######	17.4	######	9.0	#####	####	####	#####	####	######	######
	Brazil	######	12.6	######	13.0	#####	####	####	#####	####	######	######
	Chile	2.8	#####	######	#####	#####	####	####	#####	####	######	######
	China/Taiwan	22.6	#####	######	#####	#####	####	####	#####	####	######	######
	GoM, Carribean	######	7.3	######	22.0	#####	####	####	#####	####	######	######
	Japan	20.5	#####	######	#####	#####	####	####	#####	####	######	######
	Mediteranean	######	16.4	######	22.8	#####	####	####	#####	####	######	######
	Western Europe	######	15.4	######	22.9	#####	####	####	#####	####	######	######
	Northeast America	######	9.6	######	22.4	#####	####	####	#####	####	######	######
	South Korea	21.4	#####	######	#####	#####	####	####	#####	####	######	######
	Thailand	25.4	#####	######	#####	#####	####	####	#####	####	######	######
	Mexican Westcoast	7.5	#####	######	#####	#####	####	####	#####	####	######	######
Trinidad	Arabian Sea	######	#####	23.4	#####	20.5	####	####	#####	####	######	######
	Argentina	10.3	#####	######	#####	#####	####	####	#####	####	######	######
	Brazil	5.6	#####	######	#####	#####	####	####	#####	####	######	######
	Chile	######	9.7	######	15.9	#####	####	####	#####	####	######	######
	China/Taiwan	######	24.3	######	#####	#####	####	####	#####	####	######	######
	GoM, Carribean	3.8	#####	######	#####	#####	####	####	#####	####	######	######
	Japan	######	22.2	######	#####	#####	####	####	#####	####	######	######
	Mediteranean	9.9	#####	######	#####	#####	####	####	#####	####	######	######
	Western Europe	9.2	#####	######	#####	#####	####	####	#####	####	######	######
	Northeast America	5.0	#####	######	#####	#####	####	####	#####	####	######	######
	South Korea	######	23.1	######	#####	#####	####	####	#####	####	######	######
	Thailand	######	#####	26.7	#####	26.7	####	####	#####	####	######	######
	Mexican Westcoast	######	9.1	######	#####	#####	####	####	#####	####	######	######
West Africa	Arabian Sea	######	#####	16.7	#####	20.5	####	####	#####	####	######	######
	Argentina	10.8	#####	######	#####	#####	####	####	#####	####	######	######
	Brazil	7.1	#####	######	#####	#####	####	####	#####	####	######	######
	Chile	######	19.4	######	15.8	#####	####	####	#####	####	######	######
	China/Taiwan	######	#####	22.1	#####	29.5	####	####	#####	####	######	######
	GoM, Carribean	13.2	#####	######	#####	#####	####	####	#####	####	######	######
	Japan	######	#####	24.2	#####	#####	####	####	#####	####	######	######
	Mediteranean	9.9	#####	######	#####	#####	####	####	#####	####	######	######
	Western Europe	10.0	#####	######	#####	#####	####	####	#####	####	######	######
	Northeast America	11.8	#####	######	#####	#####	####	####	#####	####	######	######
	South Korea	######	#####	23.7	#####	#####	####	####	#####	####	######	######
	Thailand	######	#####	19.9	#####	26.7	####	####	#####	####	######	######
	Mexican Westcoast	######	18.8	######	24.9	#####	####	####	#####	####	######	######

Appendix 21: Average Days at Sea (Aggregated)

Origin	Destination	DIRECT	PAN	HOPE	HORN	SUEZ	NSR	TPP	NSR 3	NWP	TTP NI	NWP NI
Gulf of Mexico	Arabian Sea	######	######	28.0	######	23.0	#####	####	######	####	######	######
	Argentina/Uruguay	15.2	######	#####	######	####	#####	####	######	####	######	######
	Baltic	13.0	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	28.8	######	25.7	#####	####	######	####	######	######
	Brazil	10.5	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	10.4	#####	20.9	####	#####	####	######	####	######	######
	China/Taiwan	######	24.5	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	0.9	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	23.4	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	######	28.9	#####	######	29.7	#####	####	######	####	######	######
	Mediteranean/Ukraine	13.3	######	#####	######	####	#####	####	######	####	######	######
	Mexican Westcoast	######	8.4	#####	######	####	#####	####	######	####	######	######
	Northeast America	4.8	######	#####	######	####	#####	####	######	####	######	######
	South Korea	24.2	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	######	######	21.8	######	24.6	#####	####	######	####	######	######
	Western Europe	11.2	######	#####	######	####	#####	####	######	####	######	######
Australia	Arabian Sea	9.6	######	#####	######	####	#####	####	######	####	######	######
	Argentina/Uruguay	######	######	20.7	21.2	####	#####	####	######	####	######	######
	Baltic	25.2	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	9.1	#####	######	####	#####	####	######	####	######	######
	Brazil	######	######	20.4	25.3	28.0	#####	####	######	####	######	######
	Chile	20.1	######	#####	######	####	#####	####	######	####	######	######
	China/Taiwan	6.6	######	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	######	27.3	27.9	######	30.5	#####	####	######	####	######	######
	Japan	8.3	######	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	5.5	######	#####	######	####	#####	####	######	####	######	######
	Mediteranean/Ukraine	######	######	25.7	######	18.8	#####	####	######	####	######	######
	Mexican Westcoast	19.3	######	#####	######	####	#####	####	######	####	######	######
	Northeast America	######	######	#####	######	26.5	#####	####	######	####	######	######
	South Korea	8.2	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	12.5	######	#####	######	####	#####	####	######	####	######	######
	Western Europe	######	######	25.8	######	22.4	#####	####	######	####	######	######
Arabian Peninsula	Arabian Sea	1.5	######	#####	######	####	#####	####	######	####	######	######
	Argentina/Uruguay	######	######	18.9	######	24.2	#####	####	######	####	######	######
	Baltic	######	######	26.2	######	16.3	#####	####	######	####	######	######
	Bay of Bengal	5.0	######	#####	######	####	#####	####	######	####	######	######
	Brazil	######	######	18.2	######	19.5	#####	####	######	####	######	######
	Chile	######	######	21.8	######	27.5	#####	####	######	####	######	######
	China/Taiwan	11.1	######	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	######	######	26.2	######	21.4	#####	####	######	####	######	######
	Japan	13.3	######	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	8.9	######	#####	######	####	#####	####	######	####	######	######
	Mediteranean/Ukraine	######	######	24.0	######	10.6	#####	####	######	####	######	######
	Mexican Westcoast	26.2	######	#####	######	####	#####	####	######	####	######	######
	Northeast America	######	######	25.9	######	18.3	#####	####	######	####	######	######
	South Korea	12.8	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	6.2	######	#####	######	####	#####	####	######	####	######	######
	Western Europe	######	######	24.0	######	14.1	#####	####	######	####	######	######
Northwest America	Arabian Sea	23.0	######	#####	######	####	#####	####	######	####	######	######
	Argentina/Uruguay	######	23.4	#####	######	19.0	#####	####	######	####	######	######
	Baltic	######	24.9	#####	######	####	19.7	18.9	19.3	22.5	15.1	20.0
	Bay of Bengal	20.2	######	#####	######	####	#####	####	######	####	######	######
	Brazil	######	17.0	#####	######	####	#####	####	######	####	######	######
	Chile	14.1	######	#####	######	####	#####	####	######	####	######	######
	China/Taiwan	13.6	######	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	######	11.4	#####	######	####	#####	####	######	####	######	######
	Japan	11.3	######	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	16.7	######	#####	######	####	#####	####	######	####	######	######
	Mediteranean/Ukraine	######	22.7	#####	######	####	24.2	23.4	23.7	24.0	19.5	21.5
	Mexican Westcoast	5.4	######	#####	######	####	#####	####	######	####	######	######
	Northeast America	0.0	15.2	#####	######	####	#####	####	######	16.1	######	13.6
	South Korea	12.8	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	25.9	######	#####	######	####	#####	####	######	####	######	######
	Western Europe	######	21.0	#####	######	####	19.3	18.5	18.8	21.1	14.6	18.5

Algeria	Arabian Sea	######	######	23.7	######	11.7	#####	####	######	####	######	######
	Argentina/Uruguay	13.7	######	#####	######	####	#####	####	######	####	######	######
	Baltic	5.7	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	24.1	######	13.9	#####	####	######	####	######	######
	Brazil	9.3	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	17.9	#####	19.3	####	#####	####	######	####	######	######
	China/Taiwan	######	######	29.3	######	20.1	25.6	24.8	25.2	26.0	21.0	23.5
	GoM, Carribean	10.8	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	######	31.4	######	22.2	22.4	21.6	22.0	23.3	17.8	20.8
	Malay Archipelago/SEA	######	######	27.0	######	17.8	28.4	27.6	27.9	30.1	23.7	27.6
	Mediteranean/Ukraine	1.7	######	#####	######	####	#####	####	######	####	######	######
	Mexican Westcoast	######	17.3	#####	######	####	#####	####	######	####	######	######
	Northeast America	7.7	######	#####	######	####	#####	####	######	####	######	######
	South Korea	######	######	30.9	######	21.7	23.4	22.6	23.0	25.1	18.8	22.6
	South/East Africa	######	######	17.1	######	12.8	#####	####	######	####	######	######
	Western Europe	3.8	######	#####	######	####	#####	####	######	####	######	######
East Africa	Arabian Sea	5.9	######	#####	######	####	#####	####	######	####	######	######
	Argentina/Uruguay	######	######	14.1	######	25.6	#####	####	######	####	######	######
	Baltic	######	######	21.3	######	17.7	#####	####	######	####	######	######
	Bay of Bengal	7.3	######	#####	######	####	#####	####	######	####	######	######
	Brazil	######	######	13.4	######	22.9	#####	####	######	####	######	######
	Chile	######	######	#####	16.9	####	#####	####	######	####	######	######
	China/Taiwan	12.5	######	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	######	######	19.4	######	21.4	#####	####	######	####	######	######
	Japan	15.2	######	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	11.0	######	#####	######	####	#####	####	######	####	######	######
	Mediteranean/Ukraine	######	######	#####	######	10.8	#####	####	######	####	######	######
	Mexican Westcoast	######	25.4	#####	24.9	####	#####	####	######	####	######	######
	Northeast America	######	######	21.1	######	19.8	#####	####	######	####	######	######
	South Korea	13.1	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	2.2	######	#####	######	####	#####	####	######	####	######	######
	Western Europe	######	######	19.2	######	15.6	#####	####	######	####	######	######
East Mediteranean	Arabian Sea	######	######	26.8	######	8.5	#####	####	######	####	######	######
	Argentina/Uruguay	16.8	######	#####	######	####	#####	####	######	####	######	######
	Baltic	8.8	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	27.2	######	10.9	#####	####	######	####	######	######
	Brazil	12.1	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	21.0	#####	22.4	####	#####	####	######	####	######	######
	China/Taiwan	######	######	32.4	######	17.0	#####	####	######	####	######	######
	GoM, Carribean	14.0	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	######	21.4	######	19.1	#####	####	######	####	######	######
	Malay Archipelago/SEA	######	######	30.1	######	14.7	#####	####	######	####	######	######
	Mediteranean/Ukraine	3.2	######	#####	######	####	#####	####	######	####	######	######
	Mexican Westcoast	######	20.5	#####	######	####	#####	####	######	####	######	######
	Northeast America	10.9	######	#####	######	####	#####	####	######	####	######	######
	South Korea	######	######	34.1	######	18.7	#####	####	######	####	######	######
	South/East Africa	######	######	20.2	######	9.7	#####	####	######	####	######	######
	Western Europe	6.7	######	#####	######	####	#####	####	######	####	######	######
Caribean	Arabian Sea	######	######	23.4	######	20.5	#####	####	######	####	######	######
	Argentina/Uruguay	10.3	######	#####	######	####	#####	####	######	####	######	######
	Baltic	11.3	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	23.9	######	22.8	#####	####	######	####	######	######
	Brazil	5.6	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	9.7	#####	15.9	####	#####	####	######	####	######	######
	China/Taiwan	######	24.3	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	2.2	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	22.2	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	######	######	26.7	######	26.7	#####	####	######	####	######	######
	Mediteranean/Ukraine	9.9	######	#####	######	####	#####	####	######	####	######	######
	Mexican Westcoast	######	9.1	#####	######	####	#####	####	######	####	######	######
	Northeast America	5.0	######	#####	######	####	#####	####	######	####	######	######
	South Korea	######	23.1	#####	######	####	#####	####	######	####	######	######
	South/East Africa	######	######	16.8	######	21.7	#####	####	######	####	######	######
	Western Europe	9.2	######	#####	######	####	#####	####	######	####	######	######
Norway, Hammerfest	Arabian Sea	######	######	#####	######	18.4	27.9	27.1	27.4	####	23.2	######
	Argentina/Uruguay	17.8	######	#####	######	####	#####	####	######	####	######	######
	Baltic	3.9	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	28.4	######	21.3	24.4	23.6	23.9	####	19.7	######
	Brazil	13.1	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	19.5	#####	23.4	####	#####	####	######	####	######	######
	China/Taiwan	######	######	#####	######	26.9	18.8	18.0	18.3	25.2	14.2	22.7
	GoM, Carribean	12.0	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	######	#####	######	29.0	15.9	15.1	15.4	23.2	11.2	20.7
	Malay Archipelago/SEA	######	######	#####	######	24.6	21.8	21.0	21.3	####	17.2	######
	Mediteranean/Ukraine	7.7	######	#####	######	####	#####	####	######	####	######	######
	Mexican Westcoast	######	18.9	#####	######	####	#####	####	######	####	######	######
	Northeast America	8.5	######	#####	######	####	#####	####	######	####	######	######
	South Korea	######	######	#####	######	28.5	16.8	16.0	16.4	23.9	12.2	21.4
	South/East Africa	######	######	21.4	######	19.6	#####	####	######	####	######	######
	Western Europe	3.7	######	#####	######	####	#####	####	######	####	######	######
Peru	Arabian Sea	######	######	#####	25.3	26.2	#####	####	######	####	######	######
	Argentina/Uruguay	######	17.4	#####	9.0	####	#####	####	######	####	######	######
	Baltic	######	16.4	#####	25.7	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	26.1	######	27.6	#####	####	######	####	######	######
	Brazil	######	12.6	#####	13.0	####	#####	####	######	####	######	######
	Chile	2.8	######	#####	######	####	#####	####	######	####	######	######
	China/Taiwan	22.6	######	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	######	7.3	#####	22.0	####	#####	####	######	####	######	######
	Japan	20.5	######	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	25.4	######	#####	######	####	#####	####	######	####	######	######
	Mediteranean/Ukraine	######	16.4	#####	22.8	####	#####	####	######	####	######	######
	Mexican Westcoast	7.5	######	#####	######	####	#####	####	######	####	######	######
	Northeast America	######	9.6	#####	22.4	####	#####	####	######	####	######	######
	South Korea	21.4	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	######	23.0	#####	19.1	####	#####	####	######	####	######	######
	Western Europe	######	15.4	#####	22.9	####	#####	####	######	####	######	######

Malay Archipelago	Arabian Sea	9.1	######	#####	######	####	#####	####	######	####	######	######
	Argentina/Uruguay	######	######	22.0	22.8	####	#####	####	######	####	######	######
	Baltic	######	######	#####	######	24.1	#####	####	######	####	######	######
	Bay of Bengal	8.9	######	#####	######	####	#####	####	######	####	######	######
	Brazil	######	######	21.3	######	27.3	#####	####	######	####	######	######
	Chile	21.7	######	#####	######	####	#####	####	######	####	######	######
	China/Taiwan	4.1	######	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	######	26.5	#####	######	28.9	#####	####	######	####	######	######
	Japan	5.7	######	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	3.9	######	#####	######	####	#####	####	######	####	######	######
	Mediteranean/Ukraine	######	######	27.0	######	18.4	#####	####	######	####	######	######
	Mexican Westcoast	17.8	######	#####	######	####	#####	####	######	####	######	######
	Northeast America	######	######	#####	######	26.1	#####	####	######	26.2	######	23.7
	South Korea	5.5	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	11.1	######	#####	######	####	#####	####	######	####	######	######
	Western Europe	######	######	#####	######	21.9	#####	####	######	####	######	######
West Africa	Arabian Sea	######	######	16.7	######	20.5	#####	####	######	####	######	######
	Argentina/Uruguay	10.8	######	#####	######	####	#####	####	######	####	######	######
	Baltic	11.8	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	0.9	16.3	######	19.6	#####	####	######	####	######	######
	Brazil	7.1	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	19.4	#####	15.8	####	#####	####	######	####	######	######
	China/Taiwan	######	######	22.1	######	29.5	#####	####	######	####	######	######
	GoM, Carribean	13.2	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	######	24.2	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	######	######	19.9	######	26.7	#####	####	######	####	######	######
	Mediteranean/Ukraine	9.9	######	#####	######	####	#####	####	######	####	######	######
	Mexican Westcoast	######	18.8	#####	24.9	####	#####	####	######	####	######	######
	Northeast America	11.8	######	#####	######	####	#####	####	######	####	######	######
	South Korea	######	######	23.7	######	####	#####	####	######	####	######	######
	South/East Africa	######	######	10.0	######	####	#####	####	######	####	######	######
	Western Europe	10.0	######	#####	######	####	#####	####	######	####	######	######
Northeast America	Arabian Sea	######	######	26.2	######	18.9	#####	####	######	####	######	######
	Argentina/Uruguay	14.2	######	#####	######	####	#####	####	######	####	######	######
	Baltic	8.7	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	27.0	######	21.7	#####	####	######	####	######	######
	Brazil	9.5	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	11.8	#####	19.8	####	#####	####	######	####	######	######
	China/Taiwan	######	23.5	#####	######	27.1	27.9	27.1	27.5	19.4	23.3	16.9
	GoM, Carribean	3.8	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	24.9	#####	######	28.7	24.4	23.6	24.0	16.8	19.8	14.3
	Malay Archipelago/SEA	######	25.5	#####	######	25.6	29.2	28.5	28.8	22.7	24.6	20.2
	Mediteranean/Ukraine	9.3	######	#####	######	####	#####	####	######	####	######	######
	Mexican Westcoast	######	9.9	#####	######	####	#####	####	######	####	######	######
	Northeast America	1.8	######	#####	######	####	#####	####	######	####	######	######
	South Korea	######	26.5	#####	######	####	24.4	23.6	24.0	18.5	19.8	16.0
	South/East Africa	######	######	20.0	######	20.6	#####	####	######	####	######	######
	Western Europe	7.0	######	#####	######	####	#####	####	######	####	######	######
Russia Kara	Arabian Sea	######	######	#####	######	18.4	18.2	17.4	17.8	####	13.6	######
	Argentina/Uruguay	19.6	######	#####	######	####	#####	####	######	####	######	######
	Baltic	5.6	######	#####	######	####	#####	####	######	####	######	######
	Bay of Bengal	######	######	#####	######	22.5	24.5	23.7	24.0	####	19.9	######
	Brazil	14.9	######	#####	######	####	#####	####	######	####	######	######
	Chile	######	21.3	#####	23.4	####	#####	####	######	####	######	######
	China/Taiwan	######	######	#####	######	28.7	17.0	16.2	16.5	####	12.4	######
	GoM, Carribean	13.8	######	#####	######	####	#####	####	######	####	######	######
	Japan	######	######	#####	######	30.8	14.1	13.3	13.6	####	9.5	######
	Malay Archipelago/SEA	######	######	#####	######	26.4	21.0	20.2	20.5	####	16.4	######
	Mediteranean/Ukraine	######	######	#####	######	21.5	#####	####	######	####	######	######
	Mexican Westcoast	8.3	######	#####	######	####	#####	####	######	####	14.5	######
	Northeast America	10.2	######	#####	######	####	#####	####	######	####	######	######
	South Korea	######	######	#####	######	30.3	15.1	14.3	14.6	####	10.5	######
	South/East Africa	######	######	23.2	######	21.4	#####	####	######	####	######	######
	Western Europe	5.2	######	#####	######	####	#####	####	######	####	######	######
Russia East	Arabian Sea	13.6	######	#####	######	####	#####	####	######	####	######	######
	Argentina/Uruguay	######	######	27.9	25.5	####	#####	####	######	####	######	######
	Baltic	######	######	#####	######	28.6	19.7	18.9	19.3	23.5	15.1	21.0
	Bay of Bengal	10.6	######	#####	######	####	#####	####	######	####	######	######
	Brazil	######	27.4	27.2	######	####	#####	####	######	27.8	######	25.3
	Chile	22.5	######	#####	######	####	#####	####	######	####	######	######
	China/Taiwan	3.0	######	#####	######	####	#####	####	######	####	######	######
	GoM, Carribean	######	22.1	#####	######	####	26.1	25.3	25.7	20.7	21.5	18.2
	Japan	1.5	######	#####	######	####	#####	####	######	####	######	######
	Malay Archipelago/SEA	7.1	######	#####	######	####	#####	####	######	####	######	######
	Mediteranean/Ukraine	######	######	#####	######	22.8	24.1	23.4	23.7	23.2	19.5	20.7
	Mexican Westcoast	13.1	######	#####	######	####	#####	####	######	####	######	######
	Northeast America	######	24.3	#####	######	####	26.9	26.1	26.4	20.7	22.2	18.2
	South Korea	1.6	######	#####	######	####	#####	####	######	####	######	######
	South/East Africa	16.3	######	#####	######	####	#####	####	######	####	######	######
	Western Europe	######	######	#####	######	26.4	20.2	19.4	19.7	22.3	15.6	19.8