Project no. 265863

ACCESS

Arctic Climate Change, Economy and Society

Instrument: Collaborative Project
Thematic Priority: Ocean.2010-1 “Quantification of climate change impacts on economic sectors in the Arctic”

D2.61 – Socio-economic costs and benefits of Arctic transport

Due date of deliverable: **28/02/2014**

Actual submission date: **22/04/2014**

Start date of project: **March 1st, 2011** Duration: **48 months**

Organisation name of lead contractor for this deliverable: **ESRI**

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Summary Report

The Potential Trade Effects of the Northern Sea Route: Implications for Shipping

By

Dr Edgar Morgenroth AcSS FeRSA

Economic and Social Research Institute

Trinity College Dublin

1. Introduction

Climate change is expected to have a range of effects. One effect that has been observed is the reduction in sea ice in the arctic. While this may have a range of negative implications for example the reduction in habitat for certain animals, the reduction in sea ice may also have some positive effects. One that has received a lot of attention in the media is the potential of the North-West and North-East (referred to in the text as Northern Sea Route) passages for shipping, given that these routes would be shorter than existing routes.

Despite the significant commentary on the potential of these Arctic shipping routes, relatively little hard analysis on this potential has been carried out. However, a proper understanding of the potential for shipping is important for a number of reasons. Firstly, with reduced shipping costs there are likely to be significant economic effects, with lower transport costs resulting in more trade and hence shipping activity. This will lead to significant economic gains from trade. Secondly, shorter sea routes imply lower CO2 and other emissions to air from shipping for a given volume of trade. Thirdly, the potential of the Arctic routes will have important implications for shipping infrastructure and raises issues regarding safety and environmental impacts.

Hong (2012) discusses a number of issues that arise with the potential development of shipping including political, legal, economic, safety and environmental challenges and highlights the need for enhanced cooperation among Arctic states and increased search and rescue capacity in the Arctic. In addition two papers have considered the shipping potential using a micro approach simulating the effect of the North-West and Northern Sea route on shipping (Somanathan et al , 2009 and Fan et al, 2012). While Somanathan et al (2009) consider the costs for the Yokohama to St. Johns (Newfoundland) or New York routes via the North-West passage compared to the Panama route. They did not find significant benefits for the Arctic route but their analysis was based on ice conditions modelled on historical records and did not incorporate substantial improvements in ice thicknesses or ice free conditions. Fan et al. (2012) analysed containerised imports to the USA using a spatial network flow model. While both papers provide important insights they focus on shipping to North America and do not cover Europe and they do not attempt to show the potential for the routes.

The approach adopted in this report differs from that of the previous research in that it focuses on trade rather than shipping, since shipping is a derived demand due to trade – without trade there is no shipping. Therefore it is important to understand the international trade flows and their drivers. Trade analysis is a large field within economics covering both significant bodies of theoretical and empirical research. Empirically trade flows tend to be investigated using what is known as the gravity model. The original plan was to analyse the existing empirical findings and to use these to estimate the trade potential and hence the potential shipping. As will be seen this approach proved problematic and new estimates had to be produced.

This summary report is organised as follows. Section 2 briefly outlines the results of the literature search and meta-analysis. Section 3 summarises the new estimates and section 4 demonstrates the shipping distance savings for port pairs and country pairs. Section 5 uses the results from the gravity model and the shipping distance savings to estimate the potential trade that could use the Northern Sea route. Section 6 summarises the findings and highlights some important implications.

2. Meta Analysis Results

With shipping driven as a derived demand due to trade it is necessary to understand trade flows to simulate the potential impact of the opening of the Northern Sea Route. To this end it was envisaged to utilise the estimates of the existing literature. The economic literature on empirical trade relationships has utilised what is known as the gravity model of international trade flows to model trade and to test various hypothesis. The model owes its success to its simple structure and the fact that it explains a significant proportion of the observed variation of trade flows across country pairs.

As the name suggests, the gravity model is based on the assumption that trade is generated by mass or economic size in the importing country, which is proxied by GDP (the gravitational force), and is inhibited by distance (friction). Thus the gravity Model relates trade to the potential demand and supply which 'pull or push' trade.Distance is included in the model to account for transport costs which intuitively increase with distance. Other types of transaction costs also tend to increase with distance which implies that the relationship between trade and distance not only reflects 'pure' transport costs.

While there are many alternative specifications of the gravity model a common specification is:

$$\log(X_{ij}) = \alpha + \beta_1 \log(Y_i)+\beta_2 \log(Y_j) +\beta_3\log(P_i)+\beta_4 \log(P_j)+ \delta_2(D_{ij})+\boldsymbol{\gamma}(\mathbf{Z})+e_{ij}$$

where X_{ij} is exports from country i to j, Y is income (GDP), P is population D_{ij} is distance between the countries and Z denotes a vector of control variables (e.g. Common language, neighbours, colonial ties etc.) and e_{ij} is an error tem.

The mode can also be respecified by assuming $\beta_1=\beta_2$:

$$\log(X_{ij}) = \alpha + \beta_1 \log(Y_iY_j) +\beta_3\log(P_i)+\beta_4 \log(P_j)+ \delta_2(D_{ij})+\boldsymbol{\gamma}(\mathbf{Z})+e_{ij}$$

Several 100 papers applying the gravity model to trade flows have been published. For the purposes of this project just over 100 papers with over 700 parameters were reviewed and an initial analysis was carried out. A more thorough met-analysis was carried out for 244 estimates from papers in high ranking journals. Meta-analysis is a way to combine the results of several studies by computing a weighted mean of the results, using the standard errors on the coefficients as weights. This approach to combining results of several studies is particularly common in the medical sciences where studies typically suffer from small sample sizes which can be compensated by combining several similar studies (see Egger, 1997). This methodology has also become popular among the social sciences in that it allows for formal testing of hypotheses related to variations of parameter estimates and the estimation of average treatment effects.

This analysis (see Table 1) revealed an average income elasticity of 0.84 suggesting that a one percent increase in the combined GDP of two countries would result in a 0.84% increase in trade and a distance elasticity of -0.81, suggesting that a one percent reduction of distance between two trading partners would increase trade by 0.81%.

Table 1 Meta Analysis Results

	Max.	Min	Mean	Meta	S.E	N
$Log(YY_{ij})$	1.16	-0.19	0.82	0.84	0.16	84
$Log(Y_i)$	1.41	0.07	0.90	0.90	0.11	137
$Log(Y_j)$	1.27	-0.03	0.94	0.67	0.08	137
$Log(D_{ij})$	-0.22	-1.68	-0.88	-0.81	0.09	236

While these estimates cold be used in a simulation, where the reduced travel distance implied by the utilisation of the Northern Sea Route, would result in a substantial increase in trade. However, the review of the published literature revealed that the distance estimates were calculated using great circle distance which are straight line distance accounting for the curvature of the earth. As Table 2 shows, these straight line distances are considerably shorter than the actual shipping distances. This would not be a significant problem if the difference were the same across all country pairs. However, as the table shows, the differences vary, and for the countries of interest in this study there are significant differences depending on latitude, with the difference between straight line and shipping distances being greater for countries located further north. Thus, the published results are likely to suffer from bias. Another, drawback of the existing literature is that it concentrates on the value of merchandise trade rather than tonnages. The parameters for tonnages may well be quite different to those for the value.

Table 2. Comparison of Shipping Distances with Straight Line Distance for Germany and Italy to selected East Asian Countries

	Shipping	Straight Line	Shipping	Straight Line
	Germany	Germany	Italy	Italy
China	20,106	7,829 (-61%)	15,718	8,132 (-48%)
Hong Kong	18,563	9,242 (-50%)	14,222	9,293 (-35%)
Indonesia	16,847	11,231 (-33%)	12,489	10,832 (-13%)
Japan	21,161	9,357 (- 56%)	16,794	9,867 (-41%)
Korea	20,596	8,590 (-58%)	16,231	8,977 (-45%)
Singapore	15,906	10,381 (-35%)	11,564	10,035 (-13%)

3. New Gravity Model Estimates

Given the shortcomings of the existing literature it was necessary to generate new estimates. To this end a new dataset was constructed. The trade data is taken from the United Nations COMTRADE database and is for exports between country pairs. The data covers the time period 1988 to 2012 and cover 163 exporting countries and 183 importing countries implying a possible 656,238 observations. However, for many country pairs data is not available and country pairs for which trade is zero are ignored[1]. Furthermore, as shipping distances are used in the analysis only countries with marine ports are considered. Thus, the maximum sample size is just under 140,000 observations. Data on GDP, Population and GDP deflators is from the World Bank, World Development Indicators. Shipping distances are from Reeds Marine Distance Tables (Caney and Reynolds, 2012). Dummy variables for a common border between two trading partners, a common language or colonial ties are taken from the CEPII database (see Meyer et al. 2010). The CEPII data for straight line distances between countries is also used in order to show the bias due to the wrong distance measure being used. Time and exporter and importer dummies are also included in the analysis to account for specific effect related to either the particular year (e.g. a global economic crisis) or country specific effects.

The model is estimated for a number of different samples. Specifically, it is estimated using all available data, a northern hemisphere ample and a sample including only countries that would benefit from the Northern Sea Route (see the next section for details). The estimates are run using both the straight line distance and the shipping distance to establish the degree of bias due to the mis-measurement of distance.

[1] Since the logarithm of the trade value is used in the analysis, zero values would be naturally dropped. However, it is potentially possible to include the zero trades, but this would require an alternative estimation technique.

While the results in all models (Table 3) are broadly in line with those found in the literature. A higher income in either the exporting or importing country increases exports, while a longer distance reduces trade. Over and above the distance effect neighbouring countries trade more, while a common language has no effect, and colonial relationship only matters for coal and to a lesser extent metallic ores. A number of results are noteworthy. Firstly, it can be seen that the parameters vary depending on the sample chosen. This does not only relate to the size of the coefficients but in relation to the population variables also the sign. Secondly, as expected there are differences for the two distance variables with the elasticity of exports with respect to distance being smaller when shipping distance is used. While for the full sample the difference between the coefficients is just 5.4% the bias is 23.3% and 19.5% for the smaller samples respectively.

Table 3. Regression Results Value of Exports, 1988 to 2012

Variable	(1) Full Sample	(2) Full Sample	(3) Northern Sample	(4) Northern Sample	(5) NSR Shorter	(6) NSR Shorter
$logGDP_{exporter}$	1.19***	1.19***	1.08***	1.08***	1.31***	1.31***
$logGDP_{importer}$	1.03***	1.03***	1.25***	1.25***	1.78***	1.78***
$logPopulation_{exporter}$	0.63***	0.63***	0.51***	0.51***	-1.80**	-1.80**
$logPopulation_{importer}$	0.04	0.04	-0.12	-0.12	-2.95***	-2.95***
logStraightLine Distance	-1.56***		-1.27***		-0.98***	
logShipping Distance		-1.48***		-1.03***		-0.82***
Neighbours	-0.01	0.49***	0.11	0.62***	-0.20	0.13
Common Language	0.95***	1.13***	0.63***	0.78***	0.59**	0.70***
Colonial Relationship	0.73***	0.62***	0.40***	0.31***	0.62**	0.34
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.78	0.78	0.81	0.81	0.88	0.89
No. Of Observations	139,166	139,166	35,108	35,108	7109	7109

Note: Standard Errors are corrected for heteroskedasticity. Significance level is denoted as follows *** p<0.01, ** p<0.05, * p<0.1

To what extent are these results that were estimated for the value of trade applicable to the volume measured in tonnes, which is important for shipping? To answer this question the gravity model was estimated using values for the total tonnage traded. Furthermore, to consider if bulk trade differs from merchandise trade the model was also estimated for dry bulk materials, namely metallic ores, coal and cement, the latter being a processed dry bulk product. The estimation used trade data from UN COMTRADE database for 2008 to 2012 for the countries for which the Northern Sea Route would be shorter.

The results are shown in table 4. The model for total tonnage, fits the observed data well and the coefficients are broadly in line with those found for the value of trade although some parameters are no longer statistically significant. The results show that increased GDP increases the total tonnage trade and a greater distance between country pairs reduces trade flows. While the models for the bulk commodities do not explain the trade flows as well as those estimated for the value of trade, they nevertheless explain the majority of the variation in the data. However, only shipping distance is consistently statistically significant, indicating that neither GDP nor population are good predictors of commodity trade. However, the fact that the coefficient for exporter GDP is consistently negative is interesting as this suggests that increasing income in the exporting country would reduce commodity exports, presumably as more of these commodities are used domestically.

Table 4 Gravity Model Estimates for Selected Dry Bulk Materials (Tonnages)

Variable	Total	Metallic Ores	Coal	Cement
$logGDP_{exporter}$	1.89**	-3.53	-4.49	-1.15
$logGDP_{importer}$	0.09	6.45**	2.23	3.42
$logPopulation_{exporter}$	-1.36*	21.72	8.40	10.32
$logPopulation_{importer}$	-1.95	-9.62	-28.85	15.57
logShipping Distance	-1.19***	-1.52***	-2.35***	-2.12***
Neighbours	0.43*	0.51	0.63	3.66***
Common Language	0.31	0.17	-0.06	0.08
Colonial Relationship	0.53**	0.78	0.51	2.24
Year Fixed Effects	Yes	Yes	Yes	Yes
Exporter Fixed Effects	Yes	Yes	Yes	Yes
Importer Fixed Effects	Yes	Yes	Yes	Yes
R^2	0.89	0.53	0.55	0.59
No. Of Observations	1664	815	465	689

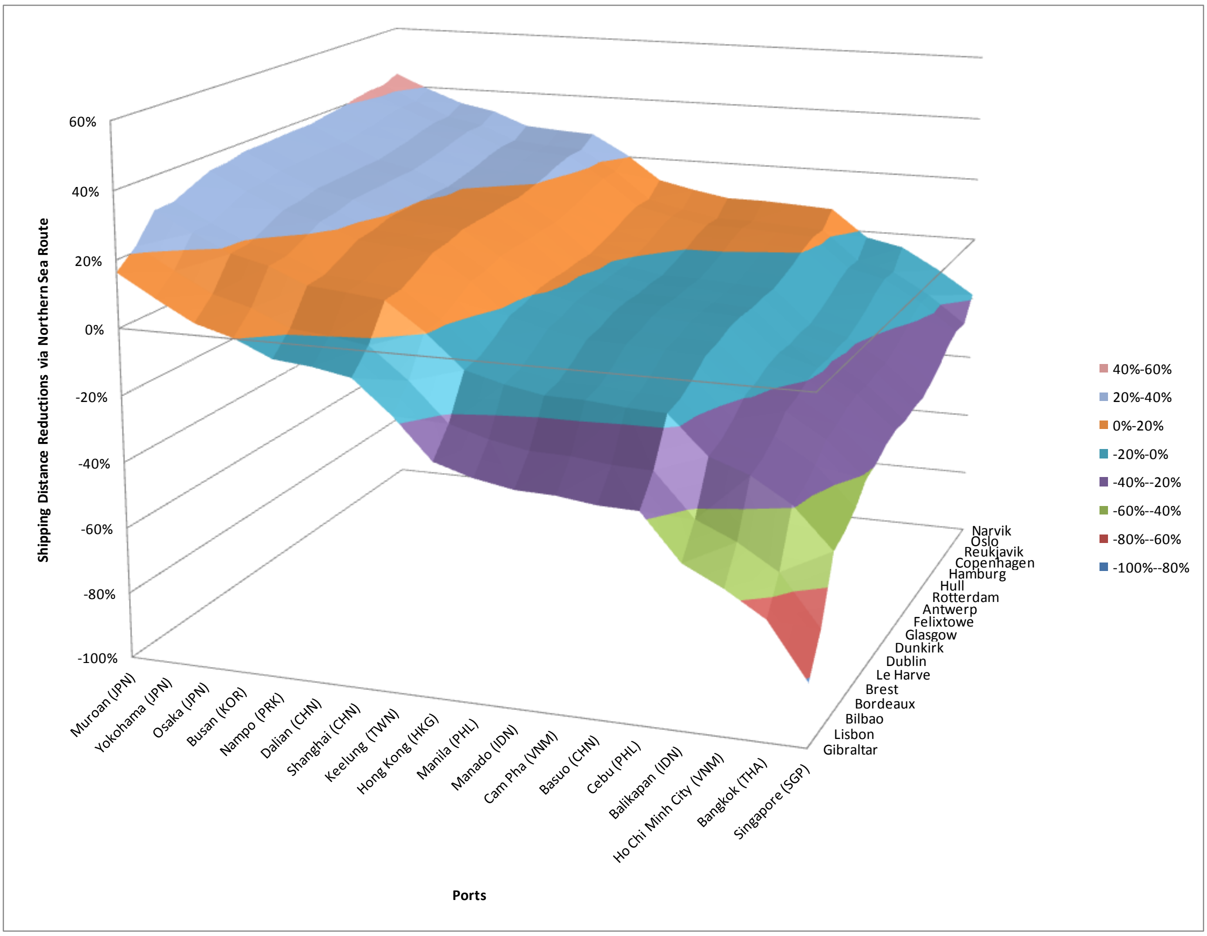
Note: Standard Errors are corrected for heteroskedasticity. Significance level is denoted as follows *** p<0.01, ** p<0.05, * p<0.1

4. Potential Shipping Distance Savings

The key determinant for the in the potential for shipping via the Northern Sea route is the degree to which the use of this route reduces shipping distances. These potential reductions in shipping distance vary across port pairs. This section considers these shipping distance reductions in detail. In doing so it is assumed that the direct route across the pole is not feasible, but that the route that is most commonly used currently.

Figure 1 shows the shipping distance reductions for selected port pairs covering East Asia and Northern Europe. The graph shows that for the most northern pair Muroan-Narvik the shipping distance reduction is over 40% while for the most southern pair the Northern Sea route would be more than 80% longer.

Figure 1. Shipping Distance Reductions Between Selected Europe and Asian Ports via the Northern Sea Route



Note: A positive value indicates a distance saving via the Northern Sea route while a negative value indicates that the Suez route is shorter.

For the analysis in this report the distance between countries is considered and table z below shows the country pairs for which the Northern Sea Route would be shorter than the Suez route. The Russian Federation is not considered here as it has access to East Asia via Vladivostock and it is also obvious that the Northern Sea Route as far as Murmansk is shorter than going to St. Petersburg. In total 104 country pairs would benefit from the Northern Sea Route if it were possible to use this for standard shipping, which implies that 208 trade flows would benefit.

The countries that benefit to varying degrees are Japan, Korea, North Korea, China, Taiwan the Philipines and Hong Kong in Asia and all of northern Europe including Norway, Denmark, Germany, Netherlands, Belgium, Great Britain, Ireland, Iceland, France, Spain, Portugal, Poland, Sweden, Finland, Estonia, Latvia and Lithuania.

Table 5. Country Pairs for Which the Northern Sea Route is Shorter than the Suez route

	Japan	Korea	North Korea	China	Taiwan	Hong Kong	Philippines
Norway	✓	✓	✓	✓	✓	✓	✓
Denmark	✓	✓	✓	✓	✓	✓	✓
Iceland	✓	✓	✓	✓	✓	✓	✓
Germany	✓	✓	✓	✓	✓	✓	✓
Finland	✓	✓	✓	✓	✓	✓	✓
Sweden	✓	✓	✓	✓	✓	✓	✓
Poland	✓	✓	✓	✓	✓	✓	✓
Estonia	✓	✓	✓	✓	✓	✓	✓
Latvia	✓	✓	✓	✓	✓	✓	✓
Lithuania	✓	✓	✓	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓	✓	✓	
Belgium	✓	✓	✓	✓	✓	✓	
Great Britain	✓	✓	✓	✓	✓		
France	✓	✓	✓	✓	✓		
Ireland	✓	✓	✓	✓	✓		
Spain	✓	✓	✓	✓			
Portugal	✓	✓	✓				

5. Trade and Shipping Implications

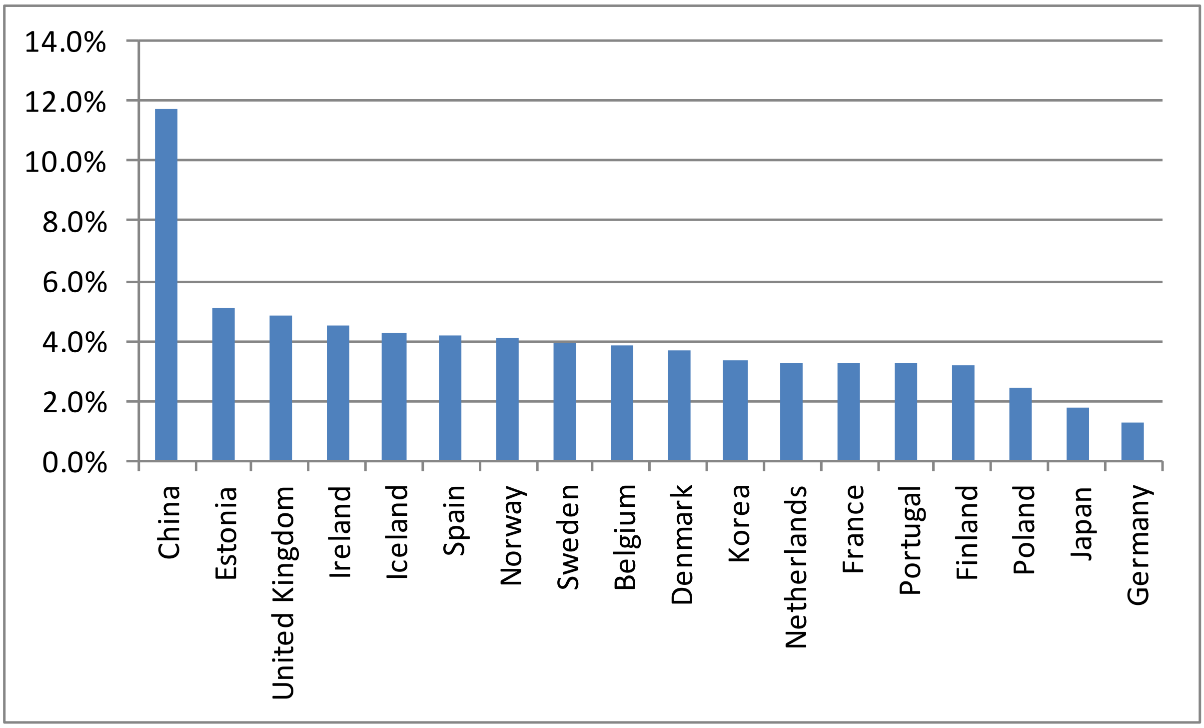
The previous section showed that only certain country pairs would benefit from the Northern Sea route. For these country pairs it would be optimal to trade via the Northern Sea route if this were a reliable shipping route, which implies that all the trade between these country pairs would use that route instead of Suez. In 2012 exports between the European and Asian trading partners excluding Taiwan and North Korea was worth 672bn US$, or roughly 3.7% of world exports and accounted for 102 million tonnes (1.1% of world trade tonnage).

In addition to the re-routing of trade, the implied lower shipping costs will stimulate additional trade, which is indicated by the distance elasticities that were estimated using the gravity model. The elasticity for the sample of countries restricted to those that would benefit from the Northern Sea Route was -0.82, indicating that a distance reduction of 1% would increase trade by 0.82%. As was shown above, the distance savings differ across country pairs and thus this additional effect also varies across the country pairs. Multiplying the distance saving for each country pair by the elasticity and multiplying this by the value of trade and summing over all country pairs generates the estimated increase in trade which amounts to 13.4% of the 2012 level of trade. Given the large distance elasticity found for total tonnage the increase in tonnage similarly calculated is larger at 17.7% which reflects that a reduction in transport costs would allow trade for goods or commodities with a lower value to weight ratio.

These estimates relate to trade in 2012. Of course in 2012 the actual shipping using the Northern Sea Route was negligible relative to this substantial potential. This is likely to be due to a range of fact including as yet relatively unfavourable ice conditions, lack of experience using the route, lack of support infrastructure and administrative constraints. However, if these obstacles are removed and ice conditions improve then more shipping is likely. However, at that point 2012 values are likely to be irrelevant. It is therefore also important to consider the likely trade volumes in the future. Given the estimated parameters this is readily accomplished once GDP projections are available (populations are assumed to be fixed). The OECD publishes long range projections for a set of countries including most of the relevant countries in this analysis[2] (see OECD, 2013). Using these (see figure 2) and the total growth up to 2030, the implied growth in trade due to GDP growth can be calculated. Given the significant growth, trade is expected to more than double using these estimates (+210% or 11.7% growth per year). However, as only the coefficients for the GDP of the exporting country was found to be significant the expected growth in tonnage is less at 120% (or 6.7% growth per year). The significant growth is particularly driven by the strong expected economic growth for China.

[2] Missing countries are Latvia, Lithuania, Hong Kong, Taiwan, North Korea and the Philippines.

Figure 2. Projected Annual Average GDP Growth between 2012 and 2060



Source OECD (2012)

By 2030 the Arctic is unlikely to be ice free throughout the year. In addition to ice conditions the infrastructure and expertise required for more extensive use of the Northern Sea Route will take time to develop. Thus, the route is likely to develop gradually. While the speed at which this development will take place cannot be known it is possible to consider a likely scenario. Take up of new technology has been found to follow a Gompertz distribution, whereby initial growth is slow but once a technology becomes more established the growth rate accelerates until near saturation has been reached when it slows down again. Thus, this distribution results in an S-shaped growth path. The take up of new shipping route is likely to follow a similar time path to the take up of a new technology although the time scale is likely to be longer. Applying such a distribution using a parameterisation whereby it takes 150 years to reach clear shipping conditions and 50 years to allow for ice free shipping during half the year it is possible to consider the likely 'penetration' of the Northern Sear route for shipping between Europe and East-Asia. It is found that under these assumptions the expected volume of trade being shipped via the Northern Sea route is just 3.7% (or almost $60 billion) of the level that would be expected if the Arctic were completely ice free and the route. However, after 30 years (2042) the volume would reach 16.1%.

It is likely that the tonnage transported via the Northern Sea route will increase faster than the value as any reduction in transport costs will benefit cargo that has a lower value to weight ratio. Furthermore, while ice and climatic conditions are still relatively unpredictable dry bulk cargo is more suitable as it is not affected by the climatic conditions and is less likely to be needed on a precise delivery date. More generally, the transportation of containerised freight of products that are susceptible to low temperatures could be problematic even if there is no ice as extremely low temperatures are likely to be experienced. Such temperature sensitive goods would need to be transported in climate controlled (heated) containers, which raises costs and thus reduces the potential benefits.

6. Summary and Implications

This report summarises the research on the trade and consequently shipping potential though the Arctic via the Northern Sea Route. The approach taken here is to consider aggregate trade and how this is likely to evolve, given the fact that shipping activity is a derived demand due to trade. Furthermore, the country pairs which potentially benefit from the Northern Sea Route through shorter shipping distances were identified as well as the distance reductions. Empirical models of aggregate trade were estimated to recover parameters used in simulating the potential for the Northern Sea Route. The results show that potentially the trade volume that would be shipped via the Northern Sea Route is very large, accounting for just under 4% of world trade.

However, the analysis treats the Northern Sea Route as if it were a similar but shorter route to the Suez route i.e. it assumes all obstacles to significant commercial shipping are removed. Importantly such obstacles include the sea ice conditions and the implicit assumption of the analysis is that the Northern Sea Route is reliably ice free throughout the year. Clearly such conditions are unlikely to exist in the short- and perhaps even the medium-term. Likewise the underlying shipping infrastructure such as ports and search and rescue capabilities, as well as experience navigating the new route are not going to be available in the short-term. One would therefore not expect the potential shipping volume to be reached for some time. Instead it is likely that the growth in shipping using this route will be slow but will grow substantially from its current low base.

Nevertheless the analysis shows that under the right conditions the route would become a significant shipping route. From a policy perspective this suggests that it is firstly important to investigate future ice conditions. A number of additional policy implications can be identified. Firstly, to operate significant shipping via the route requires the development of the appropriate support infrastructure, including ports but also search and rescue support in case of accidents. The number of accidents is likely to increase as traffic increases even if the probability of any individual ship having an accident decreases. Related to this is the need to put in place the necessary regulatory framework (Arctic Code) to ensure the safe utilisation of the route. There will also be significant training needs for seafarers in order to safeguard the safe operation of vessels. The safe and efficient operation of the route would also be facilitated by route optimisation. Particularly in the near future when the route is not ice free or in the distant future when ice will only be encountered in the winter, accurate route optimisation would reduce accidents and facilitate the speedy passage of ships. Ships (and other structures) will encounter significantly varying conditions some of which carry a significant risk of ice cover on the ships, which poses a significant risk. This would require appropriate vessel adaptation and training of crew.

While the Northern Sea route promises significant economic gains, increased shipping along the route will also have environmental impacts. Increased shipping activity will result in increased local emissions in the Arctic. In particular this could increase the deposition of black carbon on the ice which increases the melting of the ice. While increasing emissions in the Arctic there should be a reduction of emissions along the traditional routes, which would be a benefit to those areas. Given the shorter route and assuming ice free conditions the use of the Northern Sea route would be expected to reduce emissions overall. Another negative impact on the Arctic environment is likely to be the disturbance of marine mammals through noise, pollution and a reduction of habitat (e.g. less sea ice).

7. References

Caney, R., and J. Reynolds (2012) *Reeds Marine Distance Tables. 12th Edition*. London: Adlard Coles Nautical.

Egger, M. (1997) "Meta-analysis: Principles and Procedures", *British Medical Journal*, Vol. 315:1533.

Fan, L., Wilson, W., B. Dahl (2012) "Impacts of New Routes and Ports on Spatial Competition and Containerized Imports into the United States" *Maritime Policy and Management*, Vol. 39(5)pp. 479-501.

Head, K, Mayer, T. And J. Ries (2010) "The Erosion of Colonial Trade Linkages after Independence" *Journal of International Economics*, Vol., 81, pp. 1-14.

Hong, N (2012) "The Melting Arctic and its impact on China's Maritime Transport", *Research in Transportation Economics*, Vol. 35, pp. 50-57.

OECD (2013) Economic Outlook 93, June 2013. Paris: OECD http://stats.oecd.org/Index.aspx?DataSetCode=EO93_LTB#

Somanathan, S., Flynn, P., and J. Szymanski (2009) "The Northwest Passage: A Simulation" *Transport Research Part A*, Vol. 43 pp. 127-135.