Melting Ice Caps and the Economic Impact of Opening the Northern Sea Route

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Abstract

A consequence of melting Arctic ice caps is the commercial viability of the Northern Sea Route, connecting North-East Asia with North-Western Europe. This will represent a sizeable reduction in shipping distances and a decrease in the average transportation days by around one-third compared to the currently used Southern Sea Route. We examine the economic impact of the opening of the Northern Sea Route. This includes a remarkable shift of bilateral trade flows between Asia and Europe, diversion of trade within Europe, heavy shipping traffic in the Arctic, and a substantial drop in traffic through Suez. These global trade changes are reflected in real income effects for the countries involved and moderate labour displacement for specific industries. The estimated redirection of trade has also major geopolitical implications: the reorganisation of global supply chains within Europe and between Europe and Asia, and the highlighted political interest and environmental pressure on the Arctic.

Keywords: Northern Sea Route, trade forecasting, gravity model, CGE models, trade and emissions
JEL Classification: R4, F17, C2, D58, F18

1 Introduction

Arctic ice caps have been melting as a result of global warming (Kay et al., 2011; Day et al., 2012). The steady reduction of the Arctic sea ice has been well documented (Rodrigues, 2008; Kinnard et al., 2011; Comiso, 2012), and there is broad agreement on continued ice reductions through this century (Wang and Overland, 2009; Vavrus et al., 2012).[1] Recent satellite observations, furthermore, suggest that the climate model simulations may be underestimating the melting rate and the melting process

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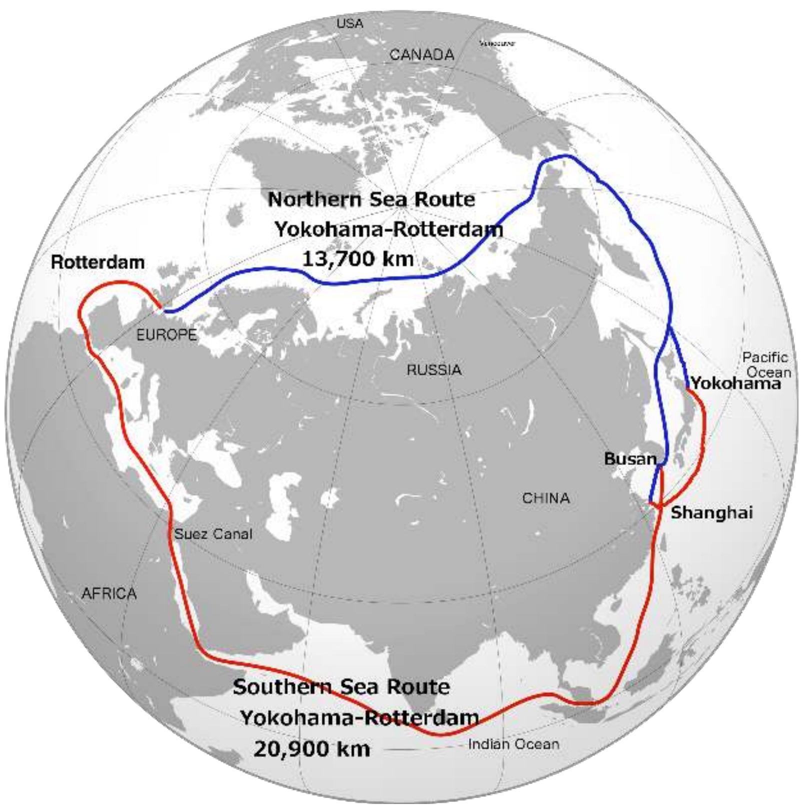
[1] The ice caps in Greenland and Antarctica have also been melting at an ever-quicker pace since 1992 (Shepherd *et al.*, 2012; Kerr, 2012).

can accelerate in the future(Kattsov et al., 2010; Rampal et al., 2011). This implies that in the recent future the extension of the Arctic ice caps will be greatly reduced and even completely ice-free during the summer. Besides the environmental effects, another consequence of this climatic phenomenon is the possibility of opening up the Northern Sea Route (NSR) for high volume commercial traffic. This shipping route will connect North East Asia (i.e. Japan, South Korea and China) with North-Western Europe through the Arctic Ocean (see Figure 1). In practical terms, this represents a reduction in the average shipping distances and days of transportation by around one third with respect to the currently used Southern Sea Route (SSR). These reductions translate not only into fuel savings and overall transport costs, but also to significant transport time savings that may effectively force supply chains in industries between East Asia and Europe to change.

Figure 1: The NSR and SSR shipping routes



The NSR is already open during summer and a number of ships have already used the route.[2] Until 2011, there was still controversy about the feasibility of the commercial use of the NSR. However, the ever-quicker melting pace found in several

[2]According to the Northern Sea Route Information Office 211 ships used the NSR between 2011 and 2014. These include recent shipping milestones: the fastest crossing Barents Observer (2011b) and the first supertanker to use the NSR Barents Observer (2011a).

studies (Shepherd *et al.*, 2012; Kerr, 2012; Stroeve et al., 2012; Slezak, 2013) has broadened the consensus in favor of its likely commercial use in the near future. A growing number of papers find that this shipping route could be fully operational for several months or all-year round at different points in the future (cf. Verny and Grigentin, 2009; Liu and Kronbak, 2010; Khon et al., 2010; Stephenson et al., 2013).[3] As a consequence, there has been heightened economic interest on the NSR: Asia's largest exporters –Japan, South Korea and China– are already investing in ice-capable vessels, while Russia has plans to further develop this shipping lane (Astill, 2012). Accordingly, the NSR will also have concrete geopolitical implications, with an expected decline in the shipping transit through the Indian Ocean and the Suez Canal as well as heightened political interest in the Arctic. China in particular has already shown political interest in the Arctic by signing a free-trade agreement with Iceland in April 2013 and most recently –together with Japan and South Korea– it gained observer status on the Arctic Council.

Given the current uncertainties regarding the relation between the icecap melting pace and the transport logistic barriers associated with the NSR, it is hard to predict the year when the NSR will become fully operational. Throughout our study we use a what-if approach where we assume that by the year 2030 the icecaps have melted far enough and logistics issues related to navigating the Arctic have been resolved, so the NSR is fully operationally all year round.[4] In practical terms, this also implies that we use an "upper bound" scenario that assumes that the NSR becomes a perfect substitute for the SSR, and as such, all commercial shipping between North East Asia and Northern Europe will use the shorter and cheaper NSR instead of the SSR. Furthermore, since the opening of the NSR will be a gradual process that will take a number of years, the economic adjustment pattern we describe in our analysis will also be gradual.

Our economic analysis follows a three-step process. In the first step we recalculate physical distances between countries to account for water-transportation shipping routes. The second step employs a regression-based gravity model of trade to map the new distance calculations –for both the SSR and the NSR– into estimations of the bilateral trade cost reductions between trading partners at the industry level. In the third step we integrate our trade cost reduction estimates into a computable general equilibrium (CGE) model of the global economy to simulate the effect of the commercial opening of the NSR on bilateral trade flows, macroeconomic outcomes, labour effects and changes in CO_2 emissions.

We find that the NSR reduces shipping distances and time between North-Western Europe and North-East Asia by about one third. This is translated into average trade cost reductions of around 3% of the value of goods sold. These overall

[3]The differences on the approximate year and the yearly extent for which the NSR will be fully operational varies much between papers, depending on different assumptions and estimations regarding the pace of the ice caps melting and developments in the shipping industry with respect to the new route.

[4]The use of 2030 as our benchmark year is mainly for illustration purposes and the use of another year does not affect our main economic results.

trade cost reductions can further be separated between actual shipping cost reductions (i.e. fuel savings) and other transport-related trade costs (e.g. transport time savings that can effectively create new supply chains in certain industries).

Using our CGE model, we find that the direct consequence of opening-up the NSR is that international shipping (volume by distance) is reduced by 0.58%, but global trade volumes increase by 0.34%. Although global trade volume changes are not radically high, they are completely concentrated in trade increases that average around 15% between North-East Asia (i.e. China, Japan and South Korea) and North-Western Europe. We estimate that the share of World trade that is re-routed through the NSR will be of 5.8%. For instance, 13.6% of Chinese trade will use the NSR in the future. This will result in a massive shift of shipping tonnage from the currently used SSR to the NSR. Roughly 8% of World trade is currently transported through the Suez Canal, and we estimate that this share would drop by around two-thirds with a re-routing of trade over the shorter Arctic route. Since on average around 15,000 commercial ships crossed the Suez Canal yearly between 2008 and 2012, the re-routing of ships through the NSR will represent about 10,000 ships crossing the Arctic yearly.[5] This implies incentives for large-scale construction of physical infrastructure in sensitive Arctic ecosystems, heightened economic security interests linked to Arctic trade, and tremendous pressure on the facilities and economies servicing the older SSR (including Egypt and Singapore).

This huge increase in bilateral trade between these two relatively large economic zones also results in a significant diversion of trade. The bilateral trade flows between North-East Asia and North-Western Europe significantly increase at the expense of less trade with other regions. In particular, there is a sizeable reduction in intra-European trade, with less trade between North-Western Europe with South and Eastern Europe. Bilateral exports from North-Western Europe (Germany, France, The Netherlands and the UK) to/from North-East Asia (China, Japan and South Korea) increase significantly, while South European exports remain unchanged. The Eastern countries of the EU experience a combination of dramatic increases in exports to Asia (e.g. Poland and Czech Republic) with no significant changes in exports for Hungary and Romania.

The changing opportunities for trade translate into macroeconomic impacts as well: real incomes and GDP are estimated to increase modestly in the countries that benefit directly from the NSR. North-East Asia experiences the biggest gains, while North-Western Europe has less pronounced GDP increases. On the other hand, most South and Eastern European countries experience real income decreases. Hence, the disruption in intra-EU trade and regional production value chains caused by the opening of the NSR, is negatively affecting the South and Eastern EU member states. For the affected countries, these impacts –in the range of less than half a percentage point of GDP– are comparable to estimated effects from an EU-US free trade agreement, or the Doha and Uruguay Rounds of multilateral trade ne-

[5]Transit data are available from the Suez Canal Authority (http://www.suezcanal.gov.eg).

gotiations.[6] Moreover –even though there are small labour market effects at the aggregate level– we also find some significant labour relocation effects for specific at the sectoral level. However, these labour displacement effects will not represent large short-term shocks, since the NSR is expected to open to commercial shipping only gradually.

Finally, we also estimate the impact of the NSR on changes in CO_2 emissions. We find that although the much shorter shipping distances will reduce the emissions associated with water transport, these gains are all but offset by a combination of higher volumes traded between North-East Asia and North-Western Europe, and a shift in emission-intensive production to East Asia.

The paper is organised as follows. In Section 2 we analyse the logistic issues and projections for commercially using the NSR in the future. We then explain how we estimate the new water-transportation distances in Section 3 and then use these new distance measures to run the gravity model of trade in Section 4. The CGE simulations and macroeconomic results are presented in Section 5. Section 6 concludes by summarising our main results.

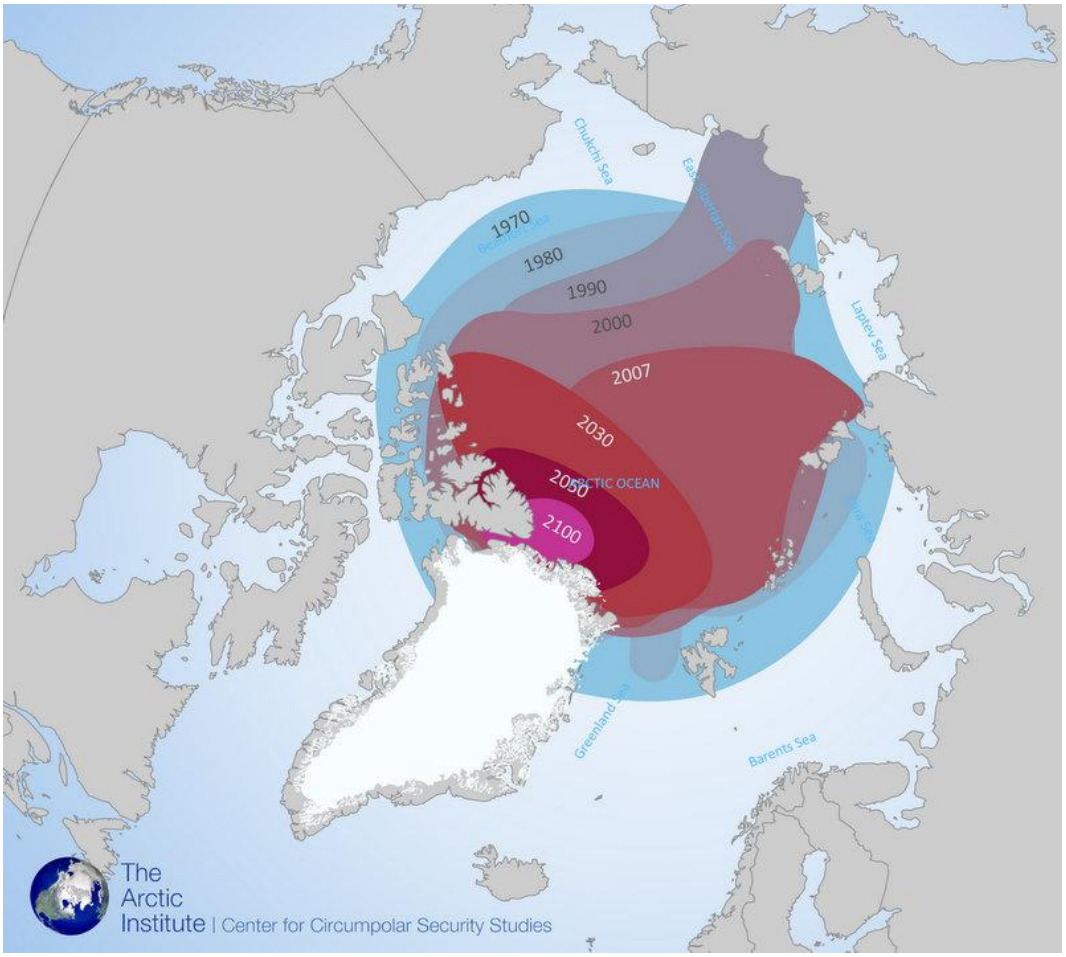
2 Commercial feasibility of the Northern Sea Route

There are two elements that condition the NSR becoming a fully viable commercial substitute of the SSR. The first is the ice levels in the Arctic, which is the main barrier to the commercial use of the NSR. A continuous and accelerating melting process will make the commercial use of the NSR more likely in the near future. Figure 2 further illustrates the current degree of ice cap melting (until 2007) and the forecasts produced by the GFDL model of the National Oceanic and Atmospheric Administration (NOAA). From this figure one can observe that by 2030 the ice cap will have melted enough to make the NSR ice-free, although it is not clear if this will be the prevalent condition year-round by then.

The second barrier to the NSR is the transport logistic issues associated with the opening of a new commercial shipping route in a region with extreme weather conditions. Even though a number of ships have already used the NSR during summer months, significant logistical obstacles remain. These include slower speeds, Russian fees and customs clearance, limited commercial weather forecasts, patchy search and rescue capabilities, scarcity of relief ports along the route and the need to use icebreakers and/or ice-capable vessels (Liu and Kronbak, 2010; Schøyen and Bråthen, 2011). These conditions not only affect the insurance premia currently charged to use the NSR, but also they limit the commercial viability of shipping operations, which are dependent on predictability, punctuality and economies of scale (Humpert and Raspotnik, 2012). However, with a yearly increasing number of ships using the NSR and the political and economic interest of Russia and other

[6] See for example Francois (2000), Francois et al. (2005), and Francois et al. (2013b).

Figure 2: Arctic Sea Ice Extent observation (1970 to 2007) and forecast (2030 to 2100)



Source: NOAA GFDL model reproduced in Humpert and Raspotnik (2012) by The Arctic Institute.

stakeholders to develop the NSR, it is expected that these logistic limitations will be gradually overcome in the near future.[7]

The uncertainties of both the pace and extent of ice cap melting and the logistical conditions associated with a fully commercial use of the NSR are translated into a wide range of estimates regarding the precise date when the NSR will be fully operational. The uncertainties regarding both elements, are also directly related and reinforce each other. In particular, a quicker pace of melting will also make it

[7]For instance, Russia created a Federal State Institution in March 2013 to administrate the NSR: The Northern Sea Route Administration (www.nsra.ru), which provides logistical assistance throughout the route. In addition, Russia has also already started setting up 10 relief ports along the route.

easier to overcome the transport logistical obstacles. Therefore, the assessments of the feasibility of the NSR range from studies that see limited use of the NSR for many years to come (cf. Lasserre and Pelletier, 2011, and papers referred therein) and more optimistic papers that foresee the commercial use of the NSR within 10 years (Verny and Grigentin, 2009).

In our study, we take a middle-point approach and use 2030 as our benchmark year, for which we assume that the NSR will be fully operational all-year round. However, our economic estimations are not dependent on this occurring precisely in 2030.[8]

The main fact needed for our estimations to be relevant, however, is that the NSR must become (at some point in time) fully commercially viable during the whole year, so it is in practical terms, a fully viable (and perfect) substitute to the SSR. This implies that we use an "upper bound" scenario that will estimate the largest expected trade and economic impact from the NSR.[9] [10]

It is important to note that the melting of the Arctic icecaps will be a global climate phenomenon with widespread ecological and economic impacts. From the economic point of view, the opening of the NSR will be one of the main impacts, but not the only one. Additional economic impacts may include the possibility to exploit natural resources in the Arctic Ocean and the Arctic region (i.e. Siberia and Northern Scandinavia), and the potential opening of the North Western Route connecting North-East Asia with the East Coast of Canada and the United States.

3 Estimating shipping distance reductions using the Northern Sea Route

As the first step of our analysis, we estimate the precise distance reductions for bilateral trade flows associated with the NSR. To do so we first need to include shipping routes in the estimation of the distance between two trading partners. Currently, the econometric literature on the gravity model of bilateral trade relies on measures of physical distances between national capitals as a measure of distance, known as the CEPII database (Mayer and Zignago, 2011).[11] However, these measures use the

[8]As a robustness analysis, in Section 5.5 we use 2015 and 2050 as different benchmark years. The use of different benchmark years affects the size of some of the results, but the main qualitative results and patterns describe for 2030 remain robust.

[9]For instance, if the NSR is not operational during winter and/or other logistic issues related to the extreme weather of the Arctic are not fully resolved, then it can be expected that shipping companies pursue a diversification strategy, using both routes conditional on which offers the lowest costs at certain seasons the year.

[10]Another potential limitation of the NSR fully substituting the SSR is the increased pressure on current transportation infrastructure. In particular, current hubs –i.e. the Port of Rotterdam– may need to expand. However, since the opening of the NSR will be a gradual process, we expect that any additional infrastructure needs can be developed while the NSR becomes fully operational.

[11]In particular, CEPII's GeoDist database (www.cepii.fr) estimates geodesic distances, which are calculated using the geographic coordinates of the capital cities. A simple measure is the distance between countries' capitals on the surface of a sphere (i.e. the great-circle formula). A

shortest physical distance and thus, are not appropriate for the present exercise. Shipping routes are usually longer than the shortest physical distance, and melting sea ice will not change the physical distance between Tokyo and London, for example.

3.1 Current shipping distances

Rather we need a more precise measure of actual shipping distances. To this end, we first build a new measure of distance between trading countries. Given the importance of ocean transport for global trade we wanted to take water distances between trading partners into account. Globally, 90 percent of world trade –and the overwhelming majority of trade between non-neighbouring countries– is carried by ship (OECD, 2011). The rest moves primarily by land. Very few exceptions use air transportation, which mainly applies for high-value commodities that need to reach the final destination in a short time (e.g. fish and flowers). For the country pairs and trade flows we focus on here, water transportation, or multi-modal transport (water and land) accounts for essentially all trade.

Therefore, to obtain more accurate measures of trade distance, we work with shipping industry data on the physical distance of shipping routes between ports in combination with land-transport distances. We continue to use CEPII's bilateral distances to represent land routes (and so the land component of combined land-water routes), while the water routes were provided by AtoBviaC.[12] As water routes we define the shortest water distances between two major ports. For each country we choose one major port. As a country's major port we define the largest and/or most significant port in terms of tons of cargo per year from ocean-going ships – except for Australia, Canada, Spain, France, Great Britain, India, Russia, United States, and South Africa, where due to the large size of these countries and their multiple accesses to water we picked two or, in the case of the US, three major ports. In the case of two trading partners with access to water, distance is calculated as the shortest land and water distance between these countries' major ports. For example we estimate the trade distance between China and The Netherlands as the shipping distance from Shanghai to Rotterdam using either the SSR or the NSR. For landlocked countries[13] we assume that a port in a neighbouring country is used, so distance between a landlocked country and a trading partner with access to water

more recent and sophisticated approach is to measure distance between two countries using the population weighted average index created by (Head and Mayer, 2010; de Sousa et al., 2012). This last measure also incorporates the internal distances of a country.

[12]This is a commercial company that offers sea distances to the maritime industry (www.atobviaonline.com/public/default.aspx). In particular, they provided us with port-to-port water distances.

[13]These are countries that do not have direct access to an ocean or an ocean-accessible water way, and thus must rely upon neighbouring countries for access to seaports. Landlocked countries in our dataset are Afghanistan, Andorra, Armenia, Austria, Azerbaijan, Belarus, Bhutan, Bolivia, Botswana, Burkina Faso, Burundi, Central African Republic, Chad, Czech Republic, Ethiopia, Hungary, Kazakhstan, Kyrgyzstan, Kosovo, Laos, Lesotho, Liechtenstein, Luxembourg, Republic of Macedonia, Malawi, Mali, Moldova, Mongolia, Nepal, Niger, Paraguay, Rwanda, San Marino,

is obtained by combining the landlocked country's land distance (from CEPII) to a neighbouring country with a major port and water distances from that port to different trading partners (from AtoBviaC). For example distance between Austria and Nepal (both landlocked) is obtained as a combination of land distance from Austria to Germany, water distance from Germany to India, and land distance from India to Nepal.

Finally, we also take into account shipping distance asymmetries. Due to sea currents, commercial shipping lanes, anti-piracy routes and country specific seafaring regulations, shipping distances from country A to country B are not the same as the distance from B to A. Hence there are asymmetries in shipping distances, which can represent up to two percentage-points differences in the distance reductions using the SSR.

3.2 New shipping distances using the NSR

For the new distances related to the opening up of the NSR, we use the estimates by Liu and Kronbak (2010).[14] Since only some countries will experiment shorter shipping distances with the opening of the NSR, we estimate the new shorter distances to Europe for a selected number of Asian and Oceanian countries.[15] Thus, we also estimated the new distances between all European countries and the selected countries above.

In Table 1 we show the great-circle formula distances, current shipping distances (using the SSR), the new NSR distances and the percentage reductions between North-East Asia's biggest exporters (China, Japan, South Korea and Taiwan) and the four Northern European countries with the busiest container ports: Netherlands (Rotterdam), Belgium (Antwerpen), Germany (Hamburg and Bremerhaven) and Great Britain (Felixstowe). The commercial use of the NSR implies a significant shipping distance reduction. For instance, the effective distance is reduced by around 37% from Japan to North European countries, while the same figure is around 31% for South Korea, 23% for China and 17% for Taiwan.

It is important to note that the NSR only makes the shipping distance shorter for countries in northern East Asia, but not for countries closer or below to the

Serbia, Slovakia, Swaziland, Switzerland, Tajikistan, Turkmenistan, Uganda, Uzbekistan, Vatican City, Zambia, Zimbabwe.

[14]They estimate that the distance reduction between Yokohama and Rotterdam using the NSR will be of 8075km. We then adjust for the distance Yokohama-Nagoya (251km) to get the Nagoya-Rotterdam reduction (7824km), which is comparable to the AtoBviaC SSR distance Nagoya-Rotterdam. For European countries south of Rotterdam we use the AtoBviaC distances between those ports to Rotterdam and then the Rotterdam-Nagoya NSR distance and then the distance from Nagoya to other Asian countries. For European countries north of Rotterdam we use the BLM Shipping 2.0 software to obtain the distance from Tromsø (Norway) to Rotterdam, and then estimate the distance Tromsø-Nagoya using the NSR. Then we use shipping distances from North European ports to Tromsø to obtain their NSR distances to Japan and the other Asian countries.

[15]These are: Japan, North and South Korea, China, Hong Kong, Taiwan, Singapore, Viet Nam, Cambodia, Philippines, Indonesia, Malaysia, Thailand, Papua New Guinea, Australia and New Zealand.

Table 1: Different distance values for selected countries

From:	To:	Great-circle formula (km)	SSR (km)	NSR (km)	NSR against SSR % change
China	Netherlands	7,831	19,942	15,436	-23%
China	Belgium	7,971	19,914	15,477	-22%
China	Germany	7,363	20,478	15,942	-22%
China	United Kingdom	8,151	19,799	14,898	-25%
Japan	Netherlands	9,303	20,996	13,172	-37%
Japan	Belgium	9,464	20,976	13,345	-36%
Japan	Germany	8,928	21,536	13,083	-39%
Japan	United Kingdom	9,574	20,779	13,182	-37%
South Korea	Netherlands	8,573	20,479	14,200	-31%
South Korea	Belgium	8,722	20,458	14,373	-30%
South Korea	Germany	8,140	21,019	14,110	-33%
South Korea	United Kingdom	8,875	20,262	14,210	-30%
Taiwan	Netherlands	9,457	18,822	15,601	-17%
Taiwan	Belgium	9,587	18,801	15,774	-16%
Taiwan	Germany	8,959	19,362	15,511	-20%
Taiwan	United Kingdom	9,790	18,605	15,611	-16%

Sources: Great-circle distances taken from the GeoDist database from CEPII. SSR and NSR distances are own estimations based on data from AtoBviaC, BLM Shipping, and Liu and Kronbak (2010).

equator. For instance, the shipping distances from the Philippines and Papua New Guinea to Northern Europe are slightly shorter using the NSR (by around 1500km), but countries that are located South and East from these countries have shorter shipping distances using the SSR (e.g. Viet Nam, Thailand, Singapore, Indonesia, Malaysia, India).

4 Gravity model of trade: Estimated linkage between shorter shipping distances and trade cost reductions

The second step in our analysis is to use the gravity model of trade to estimate the trade cost reductions associated with shorter shipping distances. The gravity model is a standard and well-known empirical workhorse in international trade. An econometrically estimated gravity model provides estimates of how much physical and socio-economic distance between partners, as well as policy, determines bilateral trade flows. We estimate trade price and distance elasticities structurally, based on the underlying theoretical structure of the trade equations in our computational model.[16] The computational model includes CES based demand for intermediate and final goods differentiated either by firm or country. This depends on whether the sector is modelled with Armington preferences, or with monopolistic competition. In both cases, trade flows can be represented as a log-linear function defined over relevant arguments. Using this functional form as our estimating equation is consistent with both the structure of the computational model, and with the recent gravity literature.[17] Importer and exporter fixed effects are used to capture structural determinants of trade that are country specific (Anderson and Yotov, 2012). Controlling for country-specific structural features of the gravity model, estimates of pairwise coefficients provide measures of the impact that distance between two trading partners has in terms of *trade costs* between the two countries. In the present context, when we substitute the current shipping distances using the SSR with the new NSR distances, we obtain a measure of how much current trade costs will be reduced by the shorter physical shipping distances associated with the NSR.

The basic estimating equation takes the following form:

$$v_{jsd} = e^{D_{js}+D_{jd}+\sum_{i}\beta_{ji}X_{isd}+\eta_{jsd}} \tag{1}$$

where the term v_{jsd} is the value of bilateral imports in sector j originating in source country s and exported to destination country d. In addition to a vector of pairwise variables X_{isd} –where i is a sector different from j– the importer and exporter fixed effects D capture country specific (i.e. not varying by partner) structural properties (Anderson and Yotov, 2012). The vector of β_{ji} coefficients apply to our pairwise variables and η_{jsd} are the error terms.

Our trade, distance, and socio-economic data for estimating equation (1) represent bilateral trade between 107 countries. Trade data are taken from COMTRADE. Data for tariffs come from the World Bank/UNCTAD WITS database. Regarding tariffs, importer fixed effects capture the most favoured nation (i.e. MFN or non-preferential) tariff, while the log difference between the MFN rate $ln(1+t_{MFN})$ and

[16] This also implies that we estimate the gravity equations at the sectoral level that is used in the computational model. Although gravity equations are usually estimated at a lower level of disaggregation, it is still expected that the model will provide adequate trade cost and estimations.

[17] See for example Anderson and van Wincoop (2003), Baldwin and Taglioni (2006), Francois and Woerz (2009), Egger et al. (2011) and Anderson and Yotov (2012).

the preferential tariff (where there is a free trade agreement or customs union) is included as a pairwise tariff variable. In addition to the shipping distances discussed above, socio-economic data are from Dür et al. (2014), the CEPII database (Mayer and Zignago, 2011), and the Quality of Governance (QoG) expert survey dataset (Teorell et al., 2011).[18] The coefficient on the tariff term is known as the trade or price elasticity. In CES based trade models, it has varying interpretations, though in the present context it serves in our structural model as an estimate of the trade substitution elasticity. Distance data, as discussed above, are based on the length of shipping routes. Following Santos Silva and Tenreyro (2006, 2011), we estimate equation (1) with a Poisson pseudo-maximum likelihood (PPML) estimator, both for total goods trade, and for trade for each sector in the computational model. The results are shown in Table 2 below.

[18] Following Egger et al. (2011), we instrument preferential trade agreements by a set of political economy variables from Teorell et al. (2011). We include polity, functioning of government, corruption, and civil liberties measures, as well as lagged trade network embeddedness (Easley and Kleinberg, 2010; De Benedictis and Tajoli, 2011; Zhou, 2011), distance, common border, common language, former colonial ties, population and GDP. Preferential trade agreements are free trade agreements and customs unions that have been agreed at least four years previously (Dür et al., 2014). The political economy variables also include pairwise measures of similarity, reflecting evidence that homophily is important in explaining direct economic and political linkages (De Benedictis and Tajoli, 2011).

Table 2: PPML gravity estimates for total trade and by sector for all goods

	TOTAL TRADE	primary agriculture	fisheries	forestry	primary energy
ln(1+tariff)	-9.529***	-3.069***	-13.272***	-4.630**	-23.111***
ln(distance)	-0.492***	-0.789***	-1.249***	-0.818***	-0.906***
common colony	0.491***	0.464**	0.433	1.939***	0.035
common language	0.290***	0.365**	-0.379**	0.159	0.557***
common border	0.616***	0.724***	1.164***	1.923***	0.794***
ln(polity)(similarity)	-87.528***	53.255	-137.983*	253.001**	-30.529
former colony	0.240**	0.0323	0.912***	0.360**	0.703***
PTA	0.310**	0.141	1.0264***	-0.184	0.240
obs	10936	10851	10130	10868	9246
R-squared	0.863	0.807	0.932	0.934	0.6409

	processed foods	beverages, tobacco	textiles	clothing	footwear
ln(1+tariff)	-2.0542***	-4.020***	-9.028***	-3.160**	-6.308***
ln(distance)	-0.702***	-0.629***	-0.603***	-0.492***	-0.262***
common colony	0.392	1.180***	-0.473*	-0.096	0.373
common language	0.373***	0.567***	0.471***	0.629***	-0.056
common border	0.743***	0.725***	0.377**	0.473***	0.591***
ln(polity)(similarity)	98.988***	213.521***	-161.982***	-183.618***	-118.760*
former colony	0.289**	0.638***	0.137	0.165	0.377**
PTA	0.142	0.444	0.523***	0.973***	0.624***
obs	10869	10880	10916	10846	10899
R-squared	0.779	0.827	0.944	0.9633	0.9739

	wood, wood products	paper, publishing	petro-chemicals	chemicals, rub-bev, plastic	metals, metal products
ln(1+tariff)	-8.916***	-7.989***	-5.466*	-4.544*	-7.475***
ln(distance)	-0.531***	-0.688***	-0.878***	-0.575***	-0.692***
common colony	0.938	0.7861***	-0.387*	0.060	0.331
common language	0.069	0.362***	0.425***	0.193**	0.015
common border	1.095***	0.984***	0.547***	0.468***	0.678***
ln(polity)(similarity)	-69.252	36.673	38.019	63.350**	7.757
former colony	0.157	0.228*	0.003	0.399***	0.330***
PTA	0.615***	0.188	0.466	0.263*	0.008
obs	10875	10871	10663	10909	10860
R-squared	0.913	0.824	0.614	0.8824	0.7196

	motor vehicles	other transport equipment	office machinery	other machines	other manufacturing
ln(1+tariff)	-12.379***	-16.007***	-31.362***	-12.613***	-10.469***
ln(distance)	-0.327***	-0.144**	-0.412***	-0.450***	-0.434***
common colony	0.690*	0.774**	0.300	0.371**	2.266***
common language	0.354**	-0.234	0.121	0.354***	0.473**
common border	0.962***	1.134***	0.438***	0.527***	-0.091
ln(polity)(similarity)	50.403	-33.382	-157.845***	-144.945***	-172.765**
former colony	-0.524***	0.529***	0.120	0.294***	0.229
PTA	0.986***	0.098	0.243	0.243	0.267
obs	10893	10873	10888	10906	19904
R-squared	0.887	0.866	0.931	0.9059	0.9097

Notes: All estimates include exporter and importer fixed effects (not shown). Significance levels: *** p<0.01, ** p<0.05, * p<0.1. Source: Own estimations.

4.1 Total trade cost reductions

Working from our data on shipping distance changes as discussed above, combined with the distance and tariff elasticities in Table 2, we can assess how much the decrease in shipping distance translates into effective trade cost reductions. The basic calculation is the following:

$$\Delta \text{cost}_{jsd} = \frac{\beta_{j,\text{distance}}}{\beta_{j,\text{tariff}}} \Delta \ln(\text{distance}_{sd}) \tag{2}$$

where Δcost_{jsd} is the change in the total cost of goods sold as a share of the value of trade. They are defined for each sector j and for bilateral trade flowing from country s to country d. Our estimates of Δcost_{jsd} are summarised in Table 3 below. Note that these total trade costs are sector-specific and are not symmetrical for country pairs. For instance, the trade costs from China to Belgium are different than from Belgium to China.

Table 3: Total trade cost reductions (average, maximum and minimum) between 20 non-services sectors for selected countries.

		trade cost reductions					trade cost reductions		
From:	To:	average	max	min	From:	To:	average	max	min
BEL	CHN	3.03	9.02	0.26	CHN	BEL	3.03	9.00	0.26
BEL	JPN	4.77	14.01	0.42	CHN	DEU	3.50	10.35	0.30
BEL	KOR	3.76	11.10	0.33	CHN	GBR	3.04	9.03	0.26
BEL	TWN	1.90	5.68	0.16	CHN	NLD	3.16	9.38	0.27
DEU	CHN	3.51	10.39	0.30	JPN	BEL	4.76	13.96	0.42
DEU	JPN	5.24	15.33	0.46	JPN	DEU	5.22	15.28	0.46
DEU	KOR	4.22	12.45	0.37	JPN	GBR	4.79	14.04	0.42
DEU	TWN	2.39	7.13	0.21	JPN	NLD	4.90	14.36	0.43
GBR	CHN	3.05	9.05	0.26	KOR	BEL	3.75	11.08	0.33
GBR	JPN	4.81	14.10	0.42	KOR	DEU	4.21	12.41	0.37
GBR	KOR	3.78	11.16	0.33	KOR	GBR	3.76	11.13	0.33
GBR	TWN	1.90	5.69	0.16	KOR	NLD	3.88	11.46	0.34
NLD	CHN	3.17	9.41	0.27	TWN	BEL	1.89	5.67	0.16
NLD	JPN	4.92	14.42	0.43	TWN	DEU	2.38	7.11	0.20
NLD	KOR	3.89	11.50	0.34	TWN	GBR	1.89	5.67	0.16
NLD	TWN	2.03	6.08	0.17	TWN	NLD	2.02	6.05	0.17

Notes: Average is the mean trade cost reductions between all 20 sectors, while max and min are the maximum and minimum trade cost reductions, respectively. Source: Own estimations.

4.2 Cost allocation between transport services and other trade costs

To link our gravity estimations with the CGE model we allocate these total trade cost reductions from Equation (2) over actual international transport services costs ("atall" in the GTAP code) and the remainder as iceberg trade cost reductions ("ams" in the GTAP code).

We first estimate the shipping services costs reduction as the percentage distance reduction associated with the NSR:

$$\text{atall}_{sd} = -\left(\frac{\text{NSRdistance}_{sd}}{\text{distance}_{sd}} - 1\right) \tag{3}$$

This reduction is applied directly to the international transport margin (ITM_{sd}), which is the wedge between the *fob* and *cif* trade values in the GTAP database. These are country specific margins: by country of origin (s) to country of destination (d). The results are presented in Table 4

Table 4: Shipping services ("atall") cost reductions for selected countries

From:	To:	% reduction	From:	To:	% reduction
BEL	CHN	24.7	CHN	BEL	24.7
BEL	JPN	36.5	CHN	DEU	28.0
BEL	KOR	29.8	CHN	GBR	24.8
BEL	TWN	16.1	CHN	NLD	25.6
DEU	CHN	28.1	JPN	BEL	36.4
DEU	JPN	39.4	JPN	DEU	39.3
DEU	KOR	33.0	JPN	GBR	36.6
DEU	TWN	19.9	JPN	NLD	37.3
GBR	CHN	24.8	KOR	BEL	29.7
GBR	JPN	36.7	KOR	DEU	32.9
GBR	KOR	29.9	KOR	GBR	29.9
GBR	TWN	16.1	KOR	NLD	30.7
NLD	CHN	25.7	TWN	BEL	16.1
NLD	JPN	37.4	TWN	DEU	19.9
NLD	KOR	30.7	TWN	GBR	16.1
NLD	TWN	17.2	TWN	NLD	17.1

Source: Own estimations.

The iceberg trade costs are then calculated as the difference between the total trade costs in Equation (2) and the shipping service cost reductions from Table 4. These iceberg trade costs account for several costs that hinder international trade, such as time, coordination, and other non-shipping service costs (cf. Hummels and Schaur, 2012). In particular, the reduction in the GTAP iceberg costs ("ams") are calculated as:

$$\text{ams}_{jsd} = \begin{cases} \Delta\text{cost}_{jsd} - (\text{atall}_{sd} * \text{ITM}_{sd}) & \text{, if positive} \\ 0 & \text{, otherwise} \end{cases} \tag{4}$$

5 CGE analysis of trade and macroeconomic outcomes

In the third and last step we integrate the trade cost reduction estimations into a computable general equilibrium (CGE) model of the global economy. Since the opening of the NSR is a global trade phenomenon that affects several countries at once, it will create inter-related shocks between different trading economies. CGE models are the standard economic tool to analyse global trade issues. They are built upon neoclassical theory, have strong micro-foundations and explicitly determine simultaneous equilibrium for a large number of markets. They provide an explicit and detailed treatment of international trade and transport margins. In particular, they are developed for the analysis of medium and long-term questions that involve inter-regional and inter-sectoral effects, and thus, CGE models are designed to assess the likely macroeconomic consequences of policy changes that affect more than one country at the same time, and can have varying effects on different economic sectors.

Trade facilitation through the NSR will not only affect bilateral trade, but also sectoral production and consumption patterns, relative domestic and international prices and the way production factors (i.e. labour, capital) are used in different countries. CGE models are routinely used in the fields of international trade, economic integration and climate change to analyse such global issues.[19] The opening of the NSR, therefore, fits within the analytical scope of CGE models since it implies a very sizeable shock to the world trade system that will affect a large set of countries simultaneously.[20]

The particular model we use is a modified version of a standard GTAP-class CGE model.[21] To assess the global general equilibrium effects of the commercial use of the Northern Sea Route, we work with the GTAP8 database, projected along the medium or SSP2 (Shared Socioeconomic Pathway) from the most recent SSPs and related Integrated Assessment scenarios (IIASA, 2012; O'Neill et al., 2012). In the paper, we focus on the year 2030 from this baseline. Our model allows us to analyse both the trade and macroeconomic implications associated with the NSR, as well as changes in CO_2 emissions from production and international transport. We aggregate the 57 GTAP sectors into 23 sectors, and the 129 regions into 39 country/regions (see Table 6 and Table 7 in the Appendix).

Working from the 2030 projection along the baseline SSP, our main CGE results are the differences between the baseline values in 2030 (i.e. the business-as-usual

[19] See for instance, Schmalensee et al. (1998), Elliott et al. (2010), Peng (2011); Beckman et al. (2011); Boehringer et al. (2011); Böhringer et al. (2012); Auffhammer and Steinhauser (2012); Dixon and Jorgenson (2013).

[20] It is important to note that recent quantitative trade models –summarised by Costinot and Rodríguez-Clare (2013)– are not able to handle the current exercise. We elaborate further on this point in the Appendix.

[21] The model characteristics are detailed in the Appendix. The main distinction between our model and the standard GTAP model is that we use a monopolistic competition framework with increasing returns to scale (*à la* Krugman, 1980), and CO_2 emissions are directly linked to production, consumption and trade. The model is implemented in GEMPACK under OSX and the model code is available upon request, as well as an executable version of the model.

scenario with no NSR shipping) compared with the counterfactual scenario where we allow bilateral trade to move through the NSR. In this counterfactual scenario, we include both the transport and trade cost reductions as discussed above into our CGE model to assess the impact on bilateral trade flows, sectoral output, and other macroeconomic variables.[22] It is important to note that our CGE models explicitly takes into account the input-output relationships within countries and sectors embodied in global value chains (GVC). Thus we can also assess how these GVC are adjusting to the new shipping distances. We also look into the social costs of these trade changes in terms of overall welfare, and employment/wage changes. Finally, we also analyse the changes that shorter shipping routes have on transport related pollution levels, which account for both shorter distances but also on potentially larger trade volumes.

Furthermore, the use of a particular benchmark year –in this case 2030– does not affect the main qualitative results presented below. In Section 5.5 we perform a robustness analysis when we also ran the CGE simulations using 2015 and 2050 as benchmark years.

5.1 Trade effects

Once we run the counterfactual simulation, we obtain global and bilateral trade changes. These changes in trade represent the difference by 2030 –when we assume that the NSR will be fully operational– between the current use of the SSR and the NSR. First, we find that using the NSR will reduce international shipping (volume by distance) by 0.58%, but global trade volumes increase by 0.34%. Although these global trade volume changes are not radically high, they are completely concentrated in trade changes between North-East Asia (i.e. China, Japan and South Korea) and Northern Europe. For instance, we estimate that the share of World trade that is re-routed through the NSR will be of 5.8%.

Table 5 shows the bilateral trade changes in trade values for goods and services for the main four North-East Asian exporters. We can observe the significant changes in export and import values of the three main Asia countries that benefit from the NSR: China, Japan, and South Korea. First, we observe how North-Western countries significantly increase their exports to China, Japan and South Korea. This group is compromised of Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Sweden, and the United Kingdom. Trade with France, Spain and Portugal is also increasing but less than in the previous group. On the other hand, trade with North-East Asia is barely changing or even decreasing for the group of Mediterranean European countries: Italy, Greece, Malta and Cyprus. An interesting case is Eastern Europe, where some countries closer to the North increase their exports to North-Eastern Asia (e.g. Czech Republic, Estonia, Latvia, Lithuania, Poland and Slovakia), while others have no significant

[22] As explained in Section 4, technically this is done through a mix of both technical efficiency in shipping and iceberg trade costs, where in total these are equivalent to estimated reductions in total trade costs.

export increases (Bulgaria, Hungary, Romania and Slovenia). In Table 8 in the Appendix we show the corresponding data for merchandise trade in volumes, which shows a similar pattern to the one described above.

This remarkable increase in bilateral trade between two relatively large economic zones is translated into a significant diversion of trade –i.e. the bilateral trade flows between North-East Asia and North-Western Europe significantly increase at the expense of less trade with other regions. The main diversion effect is that there is a sizeable reduction in intra-European trade, with less trade between North-Western Europe with South and Eastern Europe. Figure 3 shows these trade diversion patterns.

Table 5: Northeast Asia, changes in trade values for goods and services, percentage changes

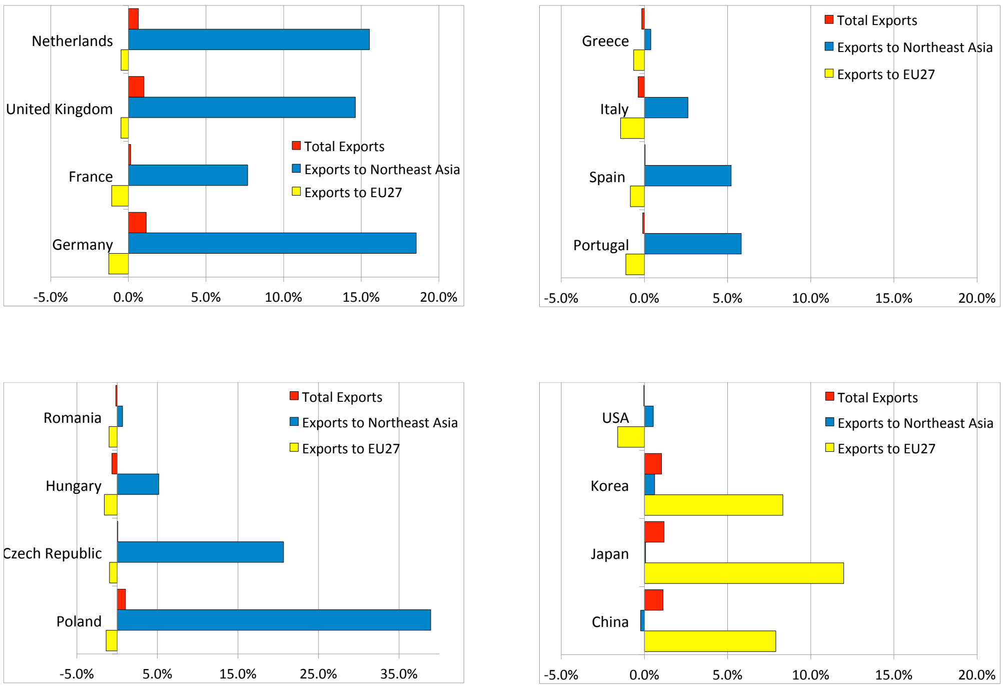
	China		Japan		South Korea	
	exports	imports	exports	imports	exports	imports
1 AUT	13.97	15.89	15.63	23.42	16.13	15.60
2 BEL	11.89	21.09	24.24	19.23	24.12	18.56
3 CYP	-1.22	0.36	-1.05	0.64	-0.99	0.03
4 CZE	11.37	22.75	13.65	22.51	11.21	22.01
5 DNK	13.86	17.39	6.12	24.65	5.96	17.82
6 EST	15.60	26.51	10.95	38.15	18.46	21.68
7 FIN	11.68	16.36	10.58	26.76	14.43	20.46
8 FRA	3.18	6.58	10.97	14.79	7.53	9.09
9 DEU	10.56	18.94	14.89	20.56	9.37	20.01
10 GRC	-1.10	0.36	-0.17	1.12	-0.87	0.08
11 HUN	-1.17	3.82	6.35	8.63	2.49	5.80
12 IRL	6.24	13.05	6.74	19.44	13.99	17.88
13 ITA	-1.88	1.24	7.05	8.33	2.28	4.47
14 LVA	19.63	35.13	6.36	23.80	13.47	27.40
15 LTU	16.78	51.29	10.04	28.65	17.90	29.53
16 LUX	7.12	12.05	2.37	2.23	0.43	6.92
17 MLT	-1.43	1.92	-1.17	0.44	-0.59	1.40
18 NLD	9.59	16.73	14.72	19.39	16.04	19.17
19 POL	16.38	42.46	15.02	23.25	9.61	21.98
20 PRT	2.10	7.35	4.66	3.40	4.73	2.31
21 SVK	8.94	16.69	16.91	13.77	9.83	17.71
22 SVN	-0.37	2.49	6.06	9.18	6.33	4.35
23 ESP	2.42	5.37	10.51	8.20	5.45	4.98
24 SWE	11.76	19.40	14.68	27.08	10.60	20.36
25 GBR	12.04	17.20	10.82	14.48	5.89	17.09
26 BGR	-1.40	0.66	1.50	2.12	-1.11	0.54
27 ROU	-2.03	0.53	3.58	9.44	-1.14	0.89
28 NOR	13.13	32.63	15.95	30.59	3.77	15.82
29 CHN	0.00	0.00	0.37	-0.20	0.73	-0.13
30 HKG	-0.28	0.81	-0.45	0.47	0.07	0.28
31 JPN	-0.20	0.37	0.00	0.00	0.32	-0.39
32 KOR	-0.13	0.73	-0.39	0.32	0.00	0.00
33 PHL	-0.61	0.35	0.09	-0.38	-0.07	0.16
34 PNG	-5.10	0.71	-3.44	-4.36	-2.31	-5.94
35 TWN	-0.48	0.57	-0.40	0.22	0.12	0.10
36 USA	-0.46	0.72	-0.44	-0.09	-0.26	-0.03
37 OCD	-0.34	0.49	-0.22	0.08	-0.16	0.11
38 SSA	-0.49	0.49	-0.24	0.09	0.05	-0.01
39 ROW	-0.69	0.63	-0.50	0.12	-0.38	0.26

Total Northeast Asia trade with the European Union

	China		Japan		South Korea	
	exports	imports	exports	imports	exports	imports
EU27	8.02	14.51	12.09	17.33	8.05	15.01

Source: Own estimations using the GTAP database.

Figure 3: Trade flows after opening the NSR: percentage changes in exports by selected countries



Notes: The horizontal scale for the Eastern EU countries is different than the scale for the other regions. Source: Own estimations using the GTAP database.

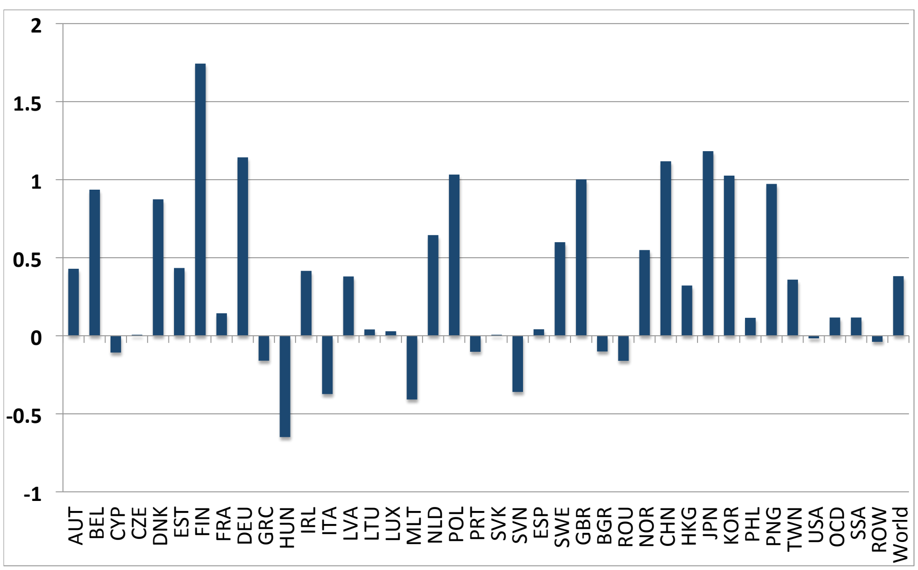
The precise figures for the countries in Figure 3 and additional countries is presented in Tables 9-10 in the Appendix. Here we can clearly observe this trade diversion pattern. First, German trade increases by around 13 % to North-East Asia (i.e. Japan, South Korea and China), while trade with other European countries slightly decreasing (by around one percentage point), with Eastern European countries experiencing the biggest decrease of almost two percentage points. This pattern of changes in German exports is also replicated by the other North-Western European countries (e.g. Austria, Belgium, Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Sweden and the United Kingdom). This is also the case for some Eastern European countries that are closer to the Baltic sea (i.e. Poland, the Czech Republic, Slovakia). France, Spain and Portugal also increase their trade with North-East Asia but at a much lower level rate of around 4%, which does not compensate for the reduction of intra-European trade and thus, overall trade barely changes for these countries. On the other hand, the remaining Mediterranean countries (Italy, Greece, Cyprus, Malta) and Eastern European countries (Hungary, Romania, Bulgaria, Slovenia) experience a decrease in trade with both Asia and Europe that is reflected in an overall reduction of trade.

Finally, the North-East Asian countries show that exports increase significantly to North-Western Europe while experiencing a slight decrease for the rest of the World (RoW), while Taiwan and Hong Kong do not experience big trade increases with Europe.

This pattern of trade diversion can also be seen when we look at exports at the sectoral level. For instance, Tables 11 and 12 in the Appendix show the sectoral changes in exports to China and Germany. We observe that sectoral exports are evenly spread among all manufacturing sectors with few exceptions (mainly the service sectors). Looking at the trade flows to Europe, in Table 12 we show the percentage changes in export sales to Germany –which has a very similar pattern from exports to other North-Western European countries. Here we find that China, Japan and South Korea significantly increase their exports to Germany in almost all sectors but services, while all other European countries decrease their exports to Germany.

Overall, even when trade diversion is significant, aggregate exports do not change significantly. In Figure 4 we show the changes in aggregate export volumes by country. We observe that North-Western European countries increase there export volumes, since the increase of exports to Asia compensates for less intra-European trade. However, Southern and Eastern European countries have a decrease in exports due to the reduction of exports to other Europe countries, which is not fully compensated by exports to third regions.

Figure 4: Changes in export values by countries, percentage changes



Source: Own estimations using the GTAP database.

5.2 Macroeconomic outcomes

The changes in trade flows are translated into macroeconomic impacts as well. First, GDP and welfare (measured as per capita utility percentage changes) are estimated to increase modestly in the countries that benefit directly from the NSR (see Figure 5).[23] North-East Asia experiences the biggest gains, while North-Western Europe has less pronounced GDP increases (with the exemption of France). On the contrary, most South and Eastern European countries experience GDP decreases. This last effect is caused by the disruption in intra-EU trade and regional production value chains caused by the opening of the NSR.[24] The associated trade diversion pattern is therefore negatively affecting the South and Eastern EU members states. To put these effects in perspective, these GDP impacts –in the range of less than half a percentage point of GDP– are comparable to estimated effects from an EU-US free trade agreement, or the Doha and Uruguay Rounds of multilateral trade negotiations.[25]

We can observe from Figure 6 that there is a direct relationship between these real income changes and the country-specific changes in exports (and overall trade volumes). In general, countries that increase their exports are those that also benefit from the opening of the NSR.

However, given the relatively small aggregate trade changes, sectoral output follows a similar pattern. From Figures 7 and 8 in the Appendix, we observe that much of the sectoral output in most EU countries does not change significantly. The only exception is a reduction in output for the sector other manufactures (S14), while clothing (S05) wood products (S20) also have a decrease for most countries.

5.3 Labour market effects

To analyse changes in the labour market we use two different CGE model closures. In the first –which is our benchmark model used to estimate the information presented so far– we assume a flexible labour supply, sticky wages and the labour market is cleared by changes in overall employment levels.[26] In the second closure, we assume the labour supply is fixed and the labour market is cleared solely by changes in wages.

In Table 14 in the Appendix, we present the changes in real wages and employment for both model closures. First, we observe that changes in real wages have a

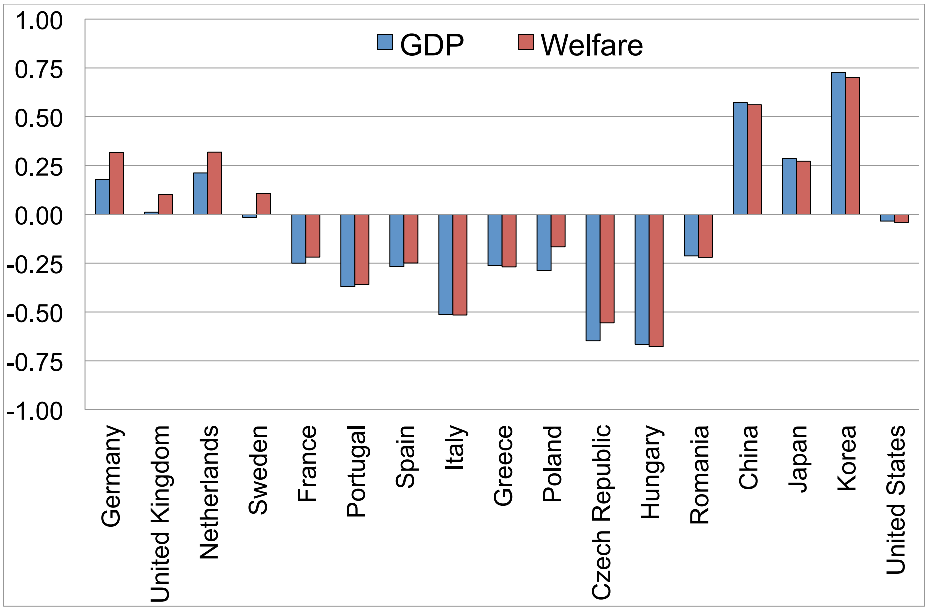
[23] See also Table 13 in the Appendix for the GDP and real income changes for all countries. There we also present two measure of welfare changes: per capita utility and equivalent variation in US$ million. Both measures of welfare experience changes that follow roughly the same pattern as GDP and real income changes; while the last welfare measure shows changes in US$ that are directly related to country size.

[24] The cases of Poland and the Czech Republic are of particular importance here. As shown above their trade with North-East Asia is increasing, as well as their overall trade, but they still have a negative GDP and welfare impact. This is associated with their lost intra-EU trade and the disruption of existing international production chains with Western European countries.

[25] See for example Francois (2000), Francois et al. (2005), and Francois et al. (2013b)).

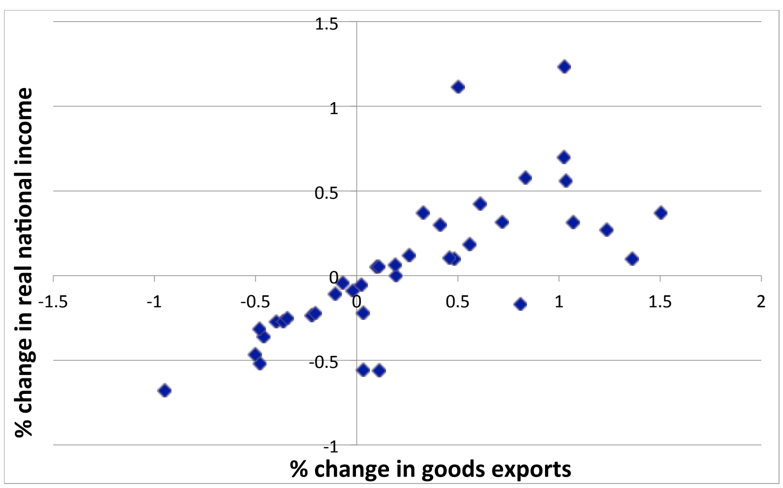
[26] We use a wage curve with an elasticity of 0.2.

Figure 5: GDP and welfare changes associated with the opening of the NSR, percentage changes



Note: Welfare is measured as per capita utility. Source: Own estimations using the GTAP database.

Figure 6: Total export values and real income percentage changes



Source: Own estimations using the GTAP database.

similar pattern to changes in real income. Countries that have declines in real wages are also expected to experience declines in real incomes. The sign and magnitude of the changes are similar between both model closures. Moreover, this pattern applies to both unskilled and skilled workers, which reflects that there are only minor changes in the relative demand of each skill level.[27]

From Table 14 we also observe that aggregate employment changes by country are negligible. For the flexible labour supply closure, changes are usually below a tenth of a percentage point –i.e. the changes in real wages are not enough to affect overall labour supply. On the other hand, in the fixed labour supply closure overall employment does not change by construction, since wages adjust to maintain full employment.

However, when we look at the sectoral level, the changes in employment are more relevant. For instance, to summarise the sectoral changes in employment we construct a labour displacement indicator, which is calculated as the weighted standard deviation of the changes in sectoral employment. This is a standardised measure of the percentage change in employment by country. Although it varies much between countries, in Table 15 in the Appendix, we observe that on average around 1% of the total labour force is displaced to another sector. Furthermore, in Table 15 we also present the sectoral changes for unskilled workers in four selected sectors. Here we observe that the sectoral displacement can be relatively high (i.e. more than 5 percentage points) for these sector in some countries.

These sectoral changes will imply some moderate efforts to help workers find new jobs, retrain and adjust to new sectors. But we do not expect large scale short-term labour adjustment shocks, since the changes in sectoral output and employment will occur gradually according to the speed at which the NSR substitutes for the SSR.

5.4 Changes in CO_2 emissions

Regarding CO_2 emissions, at first it is expected that the shorter shipping distances associated with the NSR will reduce fuel costs and emissions from the water transport sector. However, the increase in trade volumes also means that when the shipping distance is reduced, the shipping services are increased due to the jump in trade volumes between Northern Europe and North-Eastern Asia. Therefore, both effects almost offset each other, but we estimate that there is nonetheless a slight increase in global emissions of 47.8 million MT CO_2 (see Table 16 in the Appendix). This increase is comparable to the annual emissions for a small countries (e.g. Hungary and Slovakia).[28]

Note that in these simulations we assume that the implicit emission levels by sector and country remain constant. This also means that changes in emission levels are not counteracted by policy efforts (i.e. carbon taxes, emission permits) nor by

[27] This is also expected given the relatively small changes in sectoral output. The demand for skills varies by economic sectors, but if the output shares of these sectors do not change significantly, then this is reflected in small changes in relative demand for skills and the skill premium –i.e. the difference between skilled and unskilled wages.

[28] It is important to note that these particular CO_2 results are relative to the baseline scenario we chose, but different baselines would yield the same qualitative result as long as relative emission patterns are similar.

technological changes that can affect the effective emission levels by country and sector.

5.5 Using different benchmark years

As a robustness analysis –besides our benchmark case for 2030– we use different years for which the NSR is fully operational: 2015 and 2050. Both years are selected for illustrative purposes and to compare the main results with the 2030 results.

Changing the benchmark year does not affect the first two steps of our analysis: the shipping distance reductions and the gravity model results are the same. What changes is the year for which we assume that these distance and trade cost reductions are implemented. In other words, we shock the CGE model at a different year.

In general, using these alternative benchmark years the results found for 2030 are qualitatively identical with only some relatively small changes on the exact quantitative changes. For instance, we find that the size of the trade effects varies, but the trade patterns remain unchanged. Figure 9 and 10 in the Appendix are the equivalent to Figure 3 for 2030. In all three cases we can observe the same trade diversion pattern described before, while the differences relate to the exact change in bilateral trade for each country.

The same is the case when we analyse changes in GDP and welfare. When we compare Figures 11 and 12 in the Appendix with Figure 5 for 2030, we observe the same pattern of GDP and welfare changes for all three benchmark years, even though the country-specific changes are slightly different by year.[29]

The main difference between the results using a precise benchmark years can be explained by the GDP projections used in the baseline. In this sense, the 2015 projections –based on IMF data– is more reliable than the projections for later years. In particular, the growth path of Europe and East Asia is an important determinant in the size of the trade changes and these, in turn, affect the real income and GDP variations. Finally, another difference between using other benchmark years than 2030 is that the path of adjustment will be directly proportional to the exact date for which the NSR becomes fully operational.

6 Summary

The commercial use of the Northern Sea Route –if ultimately made possible by further melting of the Arctic icecap– will represent a major development for the international shipping industry. The NSR represents a reduction of about one third of the average shipping distance and days of transportation with respect to the currently used Southern Sea Route. Roughly 8% of World trade is transported through the Suez Canal and we estimate that two-thirds of this volume will be re-routed over the shorter Arctic route.

[29] In Tables 17 and 18 we show the GDP, real income, welfare and CO_2 emission changes for all regions. Moreover, the full set of results –as presented above for 2030 – are also available for 2015 and 2050 upon request.

These shorter shipping distances are associated with substantial reductions in the transportation and trade costs between two major economic regions: North-East Asia and North-Western Europe. We estimate that these overall trade costs reductions will increase the trade flows between both regions in average by around 15%, depending on the specific countries involved. This will transform the NSR into one of the busiest global trading routes, which in turn implies heightened economic and geopolitical interests linked to the Arctic and tremendous economic pressure on the countries currently servicing the older SSR (e.g. Egypt and Singapore). In addition, the NSR will also imply a large volume of trade diversion, that will have a negative economic impact on South and East Europe. We also find that there will be –for specific countries and sectors– some significant labour displacement between sectors.

Finally, we estimate that the NSR will slightly increase CO_2 emissions. Although the much shorter shipping distances will reduce the emissions associated with water transportation, these gains are offset by a combination of higher trade volumes and a shift to emission-intensive production in North-East Asia.

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References

Anderson, J. E. and E. van Wincoop (2003). “Gravity with Gravitas: A Solution to the Border Puzzle,” *American Economic Review*, 93(1), 170–192.

Anderson, J. E. and Y. Yotov (2012). “Gold Standard Gravity,” NBER Working Paper 17835.

Arkolakis, C., A. Costinot, and A. Rodríguez-Clare (2012). “New Trade Models, Same Old Gains?” *American Economic Review*, 102(1), 94–130.

Astill, J. (2012). “The Melting North,” *The Economist*, June 14th.

Auffhammer, M. and R. Steinhauser (2012). “Forecasting the Path of US CO2 Emissions Using State-Level Information,” *Review of Economics and Statistics*, 94(1), 172–185.

Baldwin, R. E. and D. Taglioni (2006). "Gravity for Dummies and Dummies for Gravity Equations," NBER Working Paper 12516.

Barents Observer (2011a). "First Supertanker along Northern Sea Route," August 24.

Barents Observer (2011b). "Speed Record on Northern Sea Route," August 17.

Beckman, J., T. Hertel, and W. Tyner (2011). "Validating Energy-oriented CGE Models," *Energy Economics*, 33, 799–806.

Boehringer, C., J. C. Carbone, and T. F. Rutherford. (2011). "Embodied Carbon Tariffs," NBER Working Paper 17376.

Böhringer, C., E. J. Balistreri, and T. F. Rutherford. (2012). "The Role of Border Carbon Adjustment in Unilateral Climate Policy: Overview of an Energy Modeling Forum Study (EMF 29)," *Energy Economics*, 34, S97–S110.

Comiso, J. C. (2012). "Large Decadal Decline of the Arctic Multiyear Ice Cover," *Journal of Climate*, 25(4), 1176–1193.

Costinot, A. and A. Rodríguez-Clare (2013). "Trade Theory with Numbers: Quantifying the Consequences of Globalization," in *Handbook of International Economics*, ed. by G. Gopinath, E. Helpman, and K. Rogoff, North Holland, vol. 4.

Day, J. J., J. C. Hargreaves, J. D. Annan, and A. Abe-Ouchi (2012). "Sources of Multi-decadal Variability in Arctic Sea Ice Extent," *Environmental Research Letters*, 7(3).

De Benedictis, L. and L. Tajoli (2011). "The World Trade Network," *World Economy*, 34(8), 1417–1454.

de Sousa, J., T. Mayer, and S. Zignago (2012). "Market Access in Global and Regional Trade," *Regional Science and Urban Economics*, 42(6), 1037–1052.

Dixon, P. and D. Jorgenson, eds. (2013). *Handbook of Computable General Equilibrium Modeling*, vol. 1, Elsevier: North Holland.

Dür, A., L. Baccini, and M. Elsig (2014). "The Design of International Trade Agreements: Introducing a New Database," *Review of International Organizations*, Forthcoming.

Easley, D. and J. Kleinberg (2010). *Networks, Crowds, and Markets: Reasoning about a Highly Connected World*, Cambridge, UK: Cambridge University Press.

Eaton, J. and S. Kortum (2002). "Technology, Geography and Trade," *Econometrica*, 70(5), 1741–1779.

Egger, P., M. Larch, K. E. Staub, and R. Winkelmann (2011). "The Trade Effects of Endogenous Preferential Trade Agreements," *American Economic Journal: Economic Policy*, 3(3), 113–143.

Elliott, J., I. Foster, S. Kortum, T. Munson, F. Perez Cervantes, and D. Weisbach (2010). "Trade and Carbon Taxes," *American Economic Review*, 100(2), 465–469.

Francois, J. F. (2000). "Assessing the Results of General Equilibrium Studies of Multilateral Trade Negotiations," Working paper, UNCTAD, Geneva.

Francois, J. F., M. Manchin, and W. Martin (2013a). "Market Structure in Multisector General Equilibrium Models of Open Economies," in *Handbook of Computable General Equilibrium Modeling*, ed. by P. Dixon and D. Jorgenson, Amsterdam: Elsevier.

Francois, J. F., M. Manchin, H. Norberg, O. Pindyuk, and P. Tomberger (2013b). "Reducing Trans-Atlantic Barriers to Trade and Investment," Final project report, Centre for Economic Policy Research (CEPR), London.

Francois, J. F. and D. Nelson (2002). "A Geometry of Specialization," *Economic Journal*, 112(481), 649–678.

Francois, J. F. and D. Roland-Holst (1997). "Scale Economies and Imperfect Competition," in *Applied Methods for Trade Policy Analysis: A Handbook*, ed. by J. F. Francois and K. A. Reinert, Cambridge: Cambridge University Press, 331–362.

Francois, J. F., H. van Mijl, and F. van Tongeren (2005). "The Doha Round and Developing Countries," *Economic Policy*, 20(42), 349–391.

Francois, J. F. and J. Woerz (2009). "Non-linear Panel Estimation of Import Quotas: The Evolution of Quota Premiums Under the ATC," *Journal of International Economics*, 78(2), 181–191.

Head, K. and T. Mayer (2010). "Illusory Border Effects: Distance Mismeasurement Inflates Estimates of Home Bias in Trade," in *The Gravity Model in International Trade: Advances and Applications*, ed. by S. Brakman and P. van Bergeijk, Cambridge: Cambridge University Press.

Hertel, T. (2013). "Global Applied General Equilibrium Analysis Using the Global Trade Analysis Project Framework," in *Handbook of Computable General Equilibrium Modeling*, ed. by P. Dixon and D. Jorgenson, Amsterdam: Elsevier: North Holland.

Hummels, D. and G. Schaur (2012). "Time as a Trade Barrier," NBER Working Paper 17758.

Humpert, M. and A. Raspotnik (2012). "The Future of Arctic Shipping," *Port Technology International*, 55, 10–11.

IIASA (2012). “Supplementary Note for the SSP Data Sets,” Database and documentation SSP2, International Institute for Applied Systems Analysis (IIASA).

Kattsov, V. M., V. E. Ryabinin, J. E. Overland, M. C. Serreze, M. Visbeck, J. E. Walsh, W. Meier, and X. Zhang (2010). “Arctic Sea Ice Change: A Grand Challenge of Climate Science,” *Journal of Glaciology*, 56, 1115–1121.

Kay, J. E., M. M. Holland, and A. Jahn (2011). “Inter-annual to Multi-decadal Arctic Sea Ice Extent Trends in a Warming World,” *Geophysical Research Letters*, 38, L15708.

Kerr, R. A. (2012). “Experts Agree Global Warming Is Melting the World Rapidly,” *Science*, 338, 1138.

Khon, V., I. I. Mokhov, M. Latif, V. A. Semenov, and W. Park (2010). “Perspectives of Northern Sea Route and Northwest Passage in the Twenty-first Century,” *Climate Change*, 100(3-4), 757–768.

Kinnard, C., C. M. Zdanowicz, D. A. Fisher, E. Isaksson, A. de Vernal, and L. G. Thompson (2011). “Reconstructed Changes in Arctic Sea Ice Over the Past 1450 Years,” *Nature*, 479, 509–513.

Krugman, P. (1980). “Scale Economies, Product Differentiation, and the Pattern of Trade,” *American Economic Review*, 70(5), 950–959.

Lasserre, F. and S. Pelletier (2011). “Polar Super Seaways? Maritime Transport in the Arctic: An Analysis of Shipowners’ Intentions,” *Journal of Transport Geography*, 19, 1465–1473.

Liu, M. and J. Kronbak (2010). “The Potential Economic Viability of Using the Northern Sea Route (NSR) as an Alternative Route Between Asia and Europe,” *Journal of Transport Geography*, 18, 434–444.

Mayer, T. and S. Zignago (2011). “Notes on CEPIIs Distances Measures: The GeoDist Database,” Document de Travail No. 2011-25, CEPII.

Narayanan, B., A. Aguiar, and R. McDougall, eds. (2012). *Global Trade, Assistance, and Production: The GTAP 8 Data Base*, Purdue University: Center for Global Trade Analysis.

OECD (2011). “Maritime Transport Costs and Their Impacts on Trade,” Report TAD/TC/WP(2009)7/REV1, Working Party of the Trade Committee, OECD, Paris.

O’Neill, B., T. Carter, K. Ebi, J. Edmonds, S. Hallegatte, E.Kemp-Benedict, E.Kriegler, L. Mearns, R. Moss, K. Riahi, B. van Ruijven, and D. van Vuuren (2012). “Workshop on The Nature and Use of New Socioeconomic Pathways for Climate Change Research,” Final meeting report, National Center for Atmospheric Research (NCAR).

Peng, X. (2011). “China’s Demographic History and Future Challenges,” *Science*, 29 July, 581–587.

Rampal, P., J. Weiss, C. Dubois, and J.-M. Campin (2011). “IPCC Climate Models Do Not Capture Arctic Sea Ice Drift Acceleration: Consequences in Terms of Projected Sea Ice Thinning and Decline,” *Journal of Geophysical Research: Oceans*, 116(C8).

Rodrigues, J. M. (2008). “The Rapid Decline of the Sea Ice in the Russian Arctic,” *Cold Regions Science and Technology*, 54, 124–142.

Rutherford, T. F. and S. V. Paltsev (2000). “GTAPinGAMS and GTAP-EG: Global Datasets for Economic Research and Illustrative Models,” Working paper, University of Colorado, Boulder.

Santos Silva, J. and S. Tenreyro (2006). “The Log of Gravity,” *Review of Economics and Statistics*, 88(4), 641–658.

Santos Silva, J. and S. Tenreyro (2011). “Further Simulation Evidence on the Performance of the Poisson Pseudo-maximum Likelihood Estimator,” *Economics Letters*, 112(2), 220–222.

Schmalensee, R., T. M. Stoker, and R. A. Judson (1998). “World Carbon Dioxide Emissions: 1950-2050,” *Review of Economics and Statistics*, 80(1), 15–27.

Schøyen, H. and S. Bråthen (2011). “The Northern Sea Route versus the Suez Canal: Cases from bulk shipping,” *Journal of Transport Geography*, 19, 977–983.

Shepherd *et al.* (2012). “A Reconciled Estimate of Ice-Sheet Mass Balance,” *Science*, 338, 1183–1189.

Slezak, M. (2013). “Antarctic Ice Melting Faster than in Past 1000 Years,” *Nature Geoscience*, 2913.

Stephenson, S. R., L. C. Smith, L. W. Brigham, and J. A. Agnew (2013). “Projected 21st-century Changes to Arctic Marine Access,” *Climate Change*, 118, 885–899.

Stroeve, J. C., M. C. Serreze, M. M. Holland, J. E. Kay, J. Malanik, and A. P. Barrett (2012). “The Arctic’s Rapidly Shrinking Sea Ice Cover: A Research Synthesis,” *Climate Change*, 110, 1005–1027.

Teorell, J., C. Dahlström, and S. Dahlberg (2011). “The QoG Expert Survey Dataset,” Report, University of Gothenburg: the Quality of Government Institute (QOG).

Vavrus, S. J., M. M. Holland, A. Jahn, D. A. Bailey, and B. A. Blazey (2012). “Twenty-first-century Arctic Climate Change in CCSM4,” *Journal of Climate*, 25(8), 2696–2710.

Verny, J. and C. Grigentin (2009). "Container Shipping on the Northern Sea Route," *International Journal of Production Economics*, 122, 107–117.

Wang, M. and J. E. Overland (2009). "A Sea Ice Free Summer Arctic Within 30 Years?" *Geophysical Research Letters*, 36, L07502.

Zhou, M. (2011). "Intensification of Geo-cultural Homophily in Global Trade: Evidence from the Gravity Model," *Social Science Research*, 40(1), 193–209.

A Appendix

A.1 CGE model summary

The CGE modeling frameworks allow for economy-wide economic analysis. By employing a balanced and internally consistent global database, in tandem with an economic model that describes economic activity for a variety of sectors and agents in the global economy, any change in exogenous variables can be assessed to understand the effects on endogenous variables in the model. The key features of a CGE framework include the model that describes economic activity and behavior, the underlying database that accounts for initial equilibrium of the global economy, as well as the suit of parameters that drive responses of agents to any given perturbation to the initial equilibrium.

A.1.1 Standard GTAP model

The particular model we use in this paper is a modified version of the standard GTAP-class CGE model. The main characteristics and references to the standard GTAP model can be found at: www.gtap.agecon.purdue.edu/models/current.asp, while Hertel (2013) and Rutherford and Paltsev (2000) provide a detailed discussion of the GTAP-class models. Here we provide a summary of this model.

The standard GTAP model describes the global economy as a whole and the interaction among economic agents. Macroeconomic factors are accounted for, including GDP, savings and investment, as well as wages and rents. Microeconomic factors are also described including supply-side factors, firms' production decisions; demand-side factors, including behavior by households and governments; factor market conditions governing labor and capital, as well as international trade. The model is employed in tandem with actual data from a given base year to quantify the effects of an economic shock that causes a movement from the initial equilibrium of the economy (see Narayanan et al. (2012) for documentation on the GTAP 8 database, and Hertel (2013) on the full database project). The initial condition of the model is that supply and demand are in balance at some equilibrium set of prices and quantities where workers are satisfied with their wages and employment, consumers are satisfied with their basket of goods, producers are satisfied with their input and output quantities and savings are fully expended on investments. Adjustment to a new equilibrium, governed by behavioral equations and parameters in the model, are largely driven by price linkage equations that link all economic activity in the market. For any perturbation to the initial equilibrium, all endogenous variables (i.e. prices and quantities) adjust simultaneously until the economy reaches a new equilibrium. Constraints on the adjustment to a new equilibrium include a suit of accounting relationships that dictate that in aggregate, the supply of goods equals the demand for goods, total exports equals total imports, all (available) workers and capital stock is employed, and global savings equals global investment; unless adjustments to these assumptions are modified for a particular application. Economic behavior drives the adjustment of quantities and prices given that consumers maximize utility given the price of goods and consumers' budget constraints, and producers minimize costs, given input prices, the level of output and production technology.

From the consumption side, the model includes a Constant Difference of Elasticities (CDE) specification for household demand. Private consumption demands for composite commodities are modeled on a per capita basis, and each region is represented by a regional household. All partial elasticities of substitution for composite commodities as well as price and income elasticities drive demand responses to economic shocks.

The standard GTAP model provides an explicit and detailed treatment of international trade and transport margins. Bilateral trade is handled via CES (constant elasticity of substitution) preferences for intermediate and final goods, using the so-called Armington assumption, where the substitution of domestics and imports –as well as product differentiation– is driven by the region of origin (i.e. by import source). This assumption is generic to most CGE models as it is a simple device to account for "cross-hauling" of trade (i.e. the empirical observation that countries often simultaneously import and export goods in the same product category).

A.1.2 Particular CGE model specification of the paper

In our model, however, we employ a modified version of the standard GTAP model that allows for monopolistic competition and increasing returns to scale (Krugman, 1980; Francois et al., 2013a).[30] In this specification there is a representative firm for each sector that produces a unique variety of the good and hence, behaves as a monopolist in their specific market.

This specification substitutes the commonly used Armington specification for import demands, by allowing the demand for differentiated intermediate products to be based on firms, or product variety, rather than over regions of origin. While firms behave as monopolists, the existence of free entry drives economic profits to zero, so that pricing is at average cost, as is the case in the standard GTAP model specification.

In particular, we use the love-of-variety –i.e. Spence-Dixit-Stiglitz (SDS)– preferences for intermediate and final goods for non-agricultural sectors. Within a representative firm, one can assume individual varieties are symmetrical in terms of selling at the same price and quantity, but that increases in the number of varieties yielding benefits because they are perceived to be different by intermediate and final demand agents. This approach can be nested within a basic CES demand system that includes both Armington- and SDS-type demand systems for individual sectors

[30] Moreover, this theoretical specification of the trade structure based on Krugman (1980), can be directly linked to a corresponding gravity equation (Costinot and Rodríguez-Clare, 2013).

using Ethier and Krugman-type monopolistic competition models –i.e. differentiated intermediate and differentiated consumer goods.[31]

Economies of scale are then modeled using the concept of variety-scaled goods. We can define 'variety-scaled output', which refers to physical quantities, with a 'scaling' or quality coefficient that reflects the varieties embodied on total physical output. This variety-scaled output can be substituted directly into an Armington-type demand system. The precise modeling in the CGE-GTAP code is done by means of a closure swap that yields output level and variety scaling effects at the sectoral level. This implies that sectoral productivity is now endogenous in the model and it adjusts to capture the output scale and variety effects.

Another key specification that is distinguishes our model is the calculation of changes in CO_2 emissions by region and sector, given the emergence of new trade routes. The inclusion of CO_2 data and the corresponding model-predicted changes in CO_2 emissions allow for the analysis of environmental impacts that are expected, given the future use of the NSR.

A.1.3 CGE model limitations and alternative model specifications

One of the limitations of CGE models is that it assumes that after an exogenous shock (e.g. a trade cost change) the economy adjusts instantly. In practice, these adjustments may take time and the costs linked to these changes (for instance, shifting production and workers between sectors, changing consumption patterns, adjusting tax revenues between different sources) may be significant and CGE models are not designed to assess these adjustment costs. Nevertheless, the magnitude of the required changes implicit in the model simulations can provide a guide into assessing these short-term costs. However, in the context of this paper, where the use of the NSR and NWR is expected to be a gradual and medium to long-term process, the required adjustments will be spread over time and thus, more easily absorbed by different regions within several years.

More recently, a series of papers analyze the welfare and overall macroeconomic outcomes of employing different market structures and trade specifications into quantitative trade models (cf. Costinot and Rodríguez-Clare, 2013). These micro-theory based econometric models are highly stylized quantification methods, that are well grounded in recent micro-economic theory, and provide clear theoretical links between market structure and the gravity equation. However, given that most of these models are single-sector specifications, their scope is very limited in terms of actual analysis, and they are not capable of dealing with detailed analysis of global trade issues. In particular, these models are not able to deal with intermediate linkages associated with global supply chains and their associated carbon emissions; on how emissions are linked to country- and sector-specific transport activities; and on how to separate actual transport costs from time related costs that are sector-specific

[31] This can be done because one can reduce Ethier-Krugman-models algebraically to Armington-type demand systems with external scale economies linked to a variety of effects (Francois and Roland-Holst, 1997; Francois and Nelson, 2002).

in nature. These are issues central to the evaluation of the economic and environmental effects of the Arctic routes that can only be tackled using a CGE model. The exception is a sub-class of models that employ a multi-sector trade structure specification following Eaton and Kortum (2002). However, these type of models are still not detailed enough to assess the effects of trade changes associated with alternative shipping routes as the NSR and NWR. In particular, they do not have an explicit international transport section, which is the key variable that explains the linkage between shipping trade cost reductions that are directly associated with the Arctic shipping lanes.

Different market structure specifications may generate different sectoral outcomes depending on the particulars of the specific sectors and how they are modeled –see Francois et al. (2013a) for a more technical discussion of demand systems and different market structures. However, at the aggregate level, there will be relatively small differences between model specifications. For example, Arkolakis et al. (2012) point out that welfare effects are similar for the different trade structure specifications.

Since the main driving force in our bilateral trade results is a reduction on the trading distance between partners that follows from the gravity model of trade, it is expected that similar bilateral trade results and overall welfare and macroeconomic effects will be found using a wider set of trade models –although the output implications can be different between both sets of models for specific sectors.

A.2 Additional tables and figures

Table 6: Sectoral description and aggregation

Code	Sector description	Aggregated GTAP sectors
S01	Agricultural products	OSD (oil seeds), C_B (sugar cane), PFB (plant-based fibbers), CTL (cattle), OAP (animal prods nec), RMK (raw milk), WOL (wool)
S02	Motor vehicles	MVH (motor vehicles and parts)
S03	Beverages and tobacco	B_T (beverages & tobacco products)
S04	Chemicals	CRP (Chemical, rubber and plastic products)
S05	Clothing	WAP (wearing apparel)
S06	Plant products	OCR (crops nec)
S07	Fisheries	FSH (fishing)
S08	Processed foods	PDR (paddy rice), WHT (wheat), GRO (cereal grains nec), V_F (vegetables & fruits), CMT (bovine meat prods), OMT (Meat prods nec), VOL (vegetable oils), MIL (diary prod), PCR (processed rice), SGR (sugar), OFD (food products nec)
S09	Leather products	LEA (leather products)
S10	Forestry	FRS (forestry)
S11	Metals	I_S (ferrous metals), NFM (metals nec), FMP (metal products)
S12	Office machinery	ELE (electronic equipment)
S13	Other machinery	OME (machinery and equipment nec
S14	Other manufactures	NMM (mineral products nec), OMF (manufactures nec)
S15	Petrochemicals and gas	P_C (Petroleum and coal products), GDT (gas manufacture and distribution)
S16	Mining and extraction	COA (coal), OIL (oil), GAS (gas), OMN (Minerals nec)
S17	Textiles	TEX (textiles)
S18	Transport equipment	OTN (transport equipment nec)
S19	Paper products and publishing	PPP (paper products and publishing)
S20	Wood products	LUM (wood products)
S21	Transport services	OTP (transport nec), WTP (water transport), ATP (air transport)
S22	Commercial services	WTR (water), CNS (construction), TRD (trade), CMN (communication), OFI (financial services nec), ISR (insurance), OBS (Business services nec)
S23	Public and consumer services	ELY (electricity), ROS (recreational and other services), OSG (Public Administration, Defence, Education, Health), DWE (dwellings)

Table 7: Regional aggregation

	Code	Country / Region		Code	Country / Region
1	AUT	Austria	21	SVK	Slovakia
2	BEL	Belgium	22	SVN	Slovenia
3	CYP	Cyprus	23	ESP	Spain
4	CZE	Czech Republic	24	SWE	Sweden
5	DNK	Denmark	25	GBR	United Kingdom
6	EST	Estonia	26	BGR	Bulgaria
7	FIN	Finland	27	ROU	Romania
8	FRA	France	28	NOR	Norway
9	DEU	Germany	29	CHN	China
10	GRC	Greece	30	HKG	Hong Kong
11	HUN	Hungary	31	JPN	Japan
12	IRL	Ireland	32	KOR	South Korea
13	ITA	Italy	33	PHL	Philippines
14	LVA	Latvia	34	PNG	Other Asia Pacific
15	LTU	Lithuania	35	TWN	Taiwan
16	LUX	Luxembourg	36	USA	United States
17	MLT	Malta	37	OCD	Other OECD
18	NLD	Netherlands	38	SSA	Sub-Sahara Africa excl. ZAF
19	POL	Poland	39	ROW	Rest of the World
20	PRT	Portugal			

Table 8: Northeast Asia, changes in trade volumes, percentage changes

	China		Japan		South Korea	
	exports	imports	exports	imports	exports	imports
1 AUT	16.80	20.17	26.60	31.18	25.64	22.51
2 BEL	12.55	21.98	27.83	30.79	27.70	24.18
3 CYP	-1.37	0.69	-1.19	2.76	-1.43	-0.40
4 CZE	12.10	24.51	15.96	32.85	15.26	26.81
5 DNK	17.24	24.61	28.44	35.79	15.68	27.99
6 EST	17.49	30.52	15.41	74.67	24.25	46.05
7 FIN	13.31	22.93	12.44	37.10	17.22	26.10
8 FRA	3.68	7.78	14.09	21.90	9.67	11.20
9 DEU	12.83	20.72	18.59	30.55	13.51	24.45
10 GRC	-1.54	0.20	0.02	3.04	-1.14	0.94
11 HUN	-1.19	5.02	7.34	14.23	3.11	9.30
12 IRL	10.98	20.33	28.93	28.63	84.83	29.19
13 ITA	-2.06	1.31	9.31	11.53	3.24	5.36
14 LVA	20.98	50.67	12.21	75.85	21.42	62.85
15 LTU	18.06	59.49	16.44	68.61	22.21	70.43
16 LUX	16.99	19.34	15.57	29.76	19.60	25.16
17 MLT	-1.57	2.00	-1.32	0.48	-0.62	1.58
18 NLD	11.20	20.50	22.91	33.99	21.17	23.95
19 POL	17.41	45.16	16.29	32.33	10.62	27.63
20 PRT	2.99	8.34	8.71	15.99	8.00	11.03
21 SVK	9.56	17.78	20.48	18.97	10.01	22.97
22 SVN	-0.41	3.04	8.76	22.57	7.69	6.59
23 ESP	2.68	5.95	13.68	15.19	7.90	9.92
24 SWE	18.02	24.14	17.66	34.02	15.67	27.59
25 GBR	13.49	21.26	15.07	28.54	9.04	23.48
26 BGR	-1.54	0.57	4.15	6.05	-1.08	0.57
27 ROU	-2.17	0.32	6.92	16.76	-1.17	1.36
28 NOR	16.27	34.88	25.31	42.85	10.19	28.42
29 CHN	0.00	0.00	0.32	-0.31	0.69	-0.29
30 HKG	-0.47	1.23	-0.53	0.41	0.00	-0.42
31 JPN	-0.31	0.32	0.00	0.00	0.23	-0.48
32 KOR	-0.29	0.69	-0.48	0.23	0.00	0.00
33 PHL	-0.68	0.30	-0.03	-0.47	-0.10	0.13
34 PNG	-5.39	0.31	-3.89	-4.53	-2.91	-6.50
35 TWN	-0.58	0.54	-0.44	0.19	0.12	0.08
36 USA	-0.55	0.54	-0.49	-0.33	-0.27	-0.21
37 OCD	-0.40	0.29	-0.28	-0.12	-0.20	-0.07
38 SSA	-0.60	0.30	-0.39	-0.10	0.06	-0.17
39 ROW	-0.79	0.47	-0.62	-0.04	-0.43	0.11

Source: Own estimations using the GTAP database.

Table 9: Changes in export values by destination region, percentage changes

	Total intra-EU,	of which: South EU	East EU	Northwest EU	Northeast Asia	Other regions	Total
Austria	-1.19	-0.32	-1.46	-1.59	23.17	0.43	0.43
Belgium	-0.20	0.57	-0.65	-0.51	19.42	0.17	0.94
Bulgaria	-0.86	-0.30	-1.01	-0.85	0.72	0.26	-0.10
Cyprus	-0.44	-0.25	-0.53	-0.43	0.29	0.17	-0.11
Czech Republic	-0.95	1.15	-1.17	-1.39	20.66	1.66	0.01
Denmark	-0.89	0.11	-1.21	-1.02	20.97	0.17	0.87
Estonia	-1.18	-0.79	-1.55	-1.05	26.48	0.59	0.43
Finland	-1.61	0.38	-2.61	-1.86	17.49	1.19	1.74
France	-1.08	-0.50	-1.66	-1.18	7.68	0.55	0.14
Germany	-1.26	-0.35	-1.89	-1.33	18.54	0.83	1.14
Greece	-0.65	-0.44	-0.43	-0.80	0.38	0.18	-0.16
Hungary	-1.60	-0.14	-1.57	-1.84	5.17	1.01	-0.65
Ireland	-0.96	0.06	-1.90	-1.08	14.81	0.78	0.42
Italy	-1.44	-0.66	-1.81	-1.45	2.61	0.36	-0.37
Latvia	-1.11	-0.49	-1.05	-1.19	27.02	0.86	0.38
Lithuania	-1.40	-1.17	-1.41	-1.39	38.02	0.40	0.04
Luxembourg	-0.56	0.05	-1.02	-0.57	8.17	0.11	0.03
Malta	-1.96	-0.51	-1.51	-1.96	1.64	0.43	-0.41
Netherlands	-0.48	0.13	-1.18	-0.44	15.53	0.56	0.64
Poland	-1.37	0.79	-1.35	-1.41	38.93	0.20	1.03
Portugal	-1.12	-0.64	-2.08	-1.23	5.82	0.51	-0.10
Romania	-1.00	-0.21	-0.53	-1.08	0.66	0.39	-0.16
Slovakia	-0.93	1.04	-0.93	-0.97	15.49	1.67	0.00
Slovenia	-1.17	-0.39	-1.23	-1.19	3.38	0.49	-0.36
Spain	-0.85	-0.42	-1.70	-0.82	5.21	0.26	0.04
Sweden	-1.04	-0.32	-1.67	-1.00	19.88	0.06	0.60
United Kingdom	-0.48	0.10	-1.14	-0.48	14.62	0.75	1.00
China	7.90	-0.20	9.58	8.57	-0.23	-0.50	1.12
Japan	11.98	7.01	10.91	4.86	0.07	-0.35	1.18
Korea	8.32	3.18	7.98	2.84	0.61	-0.26	1.03
Taiwan	1.85	-1.84	0.75	0.66	0.49	-0.14	0.36
Hong Kong	-0.05	-0.24	-0.44	0.42	0.72	0.17	0.32
USA	-1.61	-0.75	-2.41	-0.32	0.53	0.08	-0.02

Notes: South EU is: Cyprus, Greece, Italy, Malta, Portugal and Spain. East EU is: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. Northwestern EU is: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Sweden and the United Kingdom. Northeast Asia is: China, Japan, South Korea, Hong Kong and Taiwan.

Source: Own estimations using the GTAP database.

Table 10: Changes in trade values by region for selected countries, percentage changes

	Austria			**Belgium**			**Czech Republic**			**France**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	-1.2	-1.0	-1.1	-0.2	-0.9	-0.6	-1.0	-2.0	-1.4	-1.1	-0.4	-0.7
South EU	-0.3	-1.2	-0.8	0.6	-1.3	-0.3	1.2	-2.4	-0.5	-0.5	-0.8	-0.7
East EU	-1.5	-0.6	-1.0	-0.6	-1.7	-1.3	-1.2	-1.7	-1.4	-1.7	0.0	-0.9
NW EU	-1.6	-0.4	-1.0	-0.5	-0.7	-0.6	-1.4	-1.9	-1.6	-1.2	-0.1	-0.7
NE Asia	23.2	13.2	16.0	19.4	13.6	15.0	20.7	11.0	11.9	7.7	3.6	4.5
RoW	0.4	-1.2	-0.2	0.2	-1.1	-0.5	1.7	-1.5	0.2	0.5	-0.8	-0.1
TOTAL	**0.4**	**0.4**	**0.4**	**0.9**	**0.9**	**0.9**	**0.0**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**

	Germany			**Greece**			**Hungary**			**Ireland**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	-1.3	-1.2	-1.3	-0.6	0.2	-0.2	-1.6	-0.6	-1.1	-1.0	-0.6	-0.8
South EU	-0.4	-1.4	-0.9	-0.4	-0.1	-0.2	-0.1	-1.1	-0.6	0.1	-0.7	-0.3
East EU	-1.9	-1.8	-1.9	-0.4	0.3	-0.1	-1.6	-0.2	-0.8	-1.9	-1.5	-1.7
NW EU	-1.3	-1.0	-1.2	-0.8	0.3	-0.2	-1.8	-0.7	-1.4	-1.1	-0.6	-0.9
NE Asia	18.5	10.4	12.6	0.4	-0.9	-0.7	5.2	-0.3	0.2	14.8	6.2	8.2
RoW	0.8	-1.2	-0.1	0.2	-0.2	0.0	1.0	-1.0	0.2	0.8	-1.4	0.1
TOTAL	**1.1**	**1.2**	**1.2**	**-0.2**	**-0.2**	**-0.2**	**-0.6**	**-0.6**	**-0.6**	**0.4**	**0.5**	**0.4**

	Italy			**Netherlands**			**Poland**			**Portugal**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	-1.4	0.0	-0.7	-0.5	-0.9	-0.7	-1.4	-2.1	-1.7	-1.1	-0.4	-0.7
South EU	-0.7	-0.4	-0.5	0.1	-0.9	-0.3	0.8	-2.7	-1.1	-0.6	-0.6	-0.6
East EU	-1.8	0.5	-0.7	-1.2	-1.0	-1.1	-1.3	-1.8	-1.6	-2.1	0.5	-0.8
NW EU	-1.4	0.0	-0.7	-0.4	-1.0	-0.7	-1.4	-2.2	-1.8	-1.2	-0.3	-0.7
NE Asia	2.6	-1.1	-0.3	15.5	9.6	10.9	38.9	14.6	19.6	5.8	2.3	3.2
RoW	0.4	-0.5	0.0	0.6	-1.0	-0.2	0.2	-0.8	-0.4	0.5	-0.5	0.1
TOTAL	**-0.4**	**-0.4**	**-0.4**	**0.6**	**0.7**	**0.7**	**1.0**	**1.0**	**1.0**	**-0.1**	**-0.1**	**-0.1**

	Romania			**Spain**			**Sweden**			**United Kingdom**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	-1.0	0.0	-0.4	-0.8	-0.5	-0.7	-1.0	-1.6	-1.3	-0.5	-1.6	-1.1
South EU	-0.2	-0.3	-0.3	-0.4	-0.8	-0.6	-0.3	-1.9	-1.1	0.1	-1.6	-0.9
East EU	-0.5	0.2	-0.2	-1.7	-0.1	-0.9	-1.7	-1.8	-1.8	-1.1	-2.2	-1.8
NW EU	-1.1	0.0	-0.5	-0.8	-0.5	-0.7	-1.0	-1.6	-1.3	-0.5	-1.5	-1.0
NE Asia	0.7	-1.6	-0.5	5.2	3.0	3.6	19.9	11.3	13.3	14.6	10.6	11.3
RoW	0.4	0.0	0.1	0.3	-0.5	-0.1	0.1	-1.4	-0.5	0.8	-1.6	-0.3
TOTAL	**-0.2**	**-0.2**	**-0.2**	**0.0**	**0.0**	**0.0**	**0.6**	**0.7**	**0.6**	**1.0**	**1.0**	**1.0**

	China			**Japan**			**Korea**			**USA**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	7.9	14.1	9.1	12.0	16.9	13.8	8.3	15.0	10.7	-1.6	0.6	-0.4
South EU	-0.2	3.5	0.6	7.0	7.4	7.2	3.2	4.1	3.5	-0.8	0.2	-0.3
East EU	9.6	19.6	11.6	10.9	17.7	12.4	8.0	16.4	8.9	-2.4	1.1	-0.6
NW EU	8.6	14.8	9.7	4.9	3.4	4.1	2.8	2.5	2.7	-0.3	-0.1	-0.2
NE Asia	-0.2	0.6	0.2	0.1	-0.1	0.0	0.6	-0.2	0.2	0.5	-0.4	0.0
RoW	-0.5	0.7	0.1	-0.3	0.1	-0.1	-0.3	0.2	0.0	0.1	0.1	0.1
TOTAL	**1.1**	**1.4**	**1.3**	**1.2**	**1.0**	**1.1**	**1.0**	**0.9**	**1.0**	**0.0**	**0.0**	**0.0**

Notes: South EU is: Cyprus, Greece, Italy, Malta, Portugal and Spain. East EU is: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. Northwestern EU is: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Sweden and the United Kingdom. Northeast Asia is: China, Japan, South Korea, Hong Kong and Taiwan.
Source: Own estimations using the GTAP database.

Table 11: Sectoral changes in export sales to China for selected countries, percentage changes

	AUT	BEL	CZE	FRA	DEU	HUN	ITA	NLD	ESP	SWE	GBR	JPN	KOR
Sector:													
S01	27.5	24.9	28.7	9.8	29.9	5.7	2.6	26.2	7.0	33.2	26.1	2.5	1.6
S02	14.6	16.0	23.3	8.3	13.5	4.3	2.2	20.0	6.4	19.7	11.3	0.8	0.3
S03	20.9	22.2	20.7	6.9	22.4	3.1	0.8	20.0	4.9	25.7	20.3	1.3	1.7
S04	20.4	19.9	19.8	6.5	23.3	2.6	0.5	19.7	4.8	24.9	20.5	0.6	0.5
S05	15.0	16.9	14.7	4.6	15.3	2.6	0.6	13.1	3.6	16.7	12.2	0.2	0.6
S06	25.0	23.6	25.6	7.8	27.4	3.8	0.8	24.4	5.4	30.6	23.9	0.5	-1.4
S07	7.0	52.2	7.4	38.9	116.8	6.1	6.1	75.8	16.6	6.3	40.1	0.2	2.0
S08	23.2	23.3	22.3	7.9	25.6	3.7	1.1	23.3	5.5	28.0	22.1	1.4	1.4
S09	15.7	12.9	17.4	7.7	14.1	5.7	3.1	15.0	5.2	15.4	11.8	2.1	2.0
S10	25.3	12.2	0.8	7.6	15.7	0.5	0.2	22.6	7.4	31.9	29.5	2.8	1.2
S11	19.5	20.1	21.8	7.1	22.1	3.5	1.1	19.4	4.8	24.3	21.0	0.4	0.9
S12	44.2	33.3	39.3	9.6	25.0	8.6	4.0	31.4	11.5	22.0	28.2	-0.1	0.9
S13	15.1	16.4	19.1	7.0	16.2	5.5	2.0	16.0	5.9	16.5	15.0	0.0	0.8
S14	28.2	14.2	34.6	11.5	32.7	7.2	2.6	33.3	10.8	28.9	24.1	1.3	1.7
S15	29.6	28.7	30.0	8.8	33.2	0.5	0.7	29.6	5.9	36.4	28.0	0.3	0.3
S16	28.6	26.6	30.0	16.2	23.7	3.2	0.9	28.6	8.1	29.8	27.7	0.3	0.1
S17	30.3	69.2	25.8	27.7	26.8	7.7	4.0	25.9	9.1	28.0	23.3	1.8	1.5
S18	28.6	10.0	36.4	5.0	8.9	9.4	3.2	17.8	6.1	30.6	8.7	0.7	1.4
S19	20.4	21.4	31.6	8.1	23.1	5.0	1.7	23.5	5.9	32.8	20.9	0.6	1.0
S20	39.9	32.3	36.4	14.2	31.7	9.4	5.2	35.3	11.8	48.4	29.1	3.7	2.8
S21	0.5	0.6	0.5	0.4	0.6	0.6	0.2	0.5	0.4	0.7	0.5	0.1	0.2
S22	0.3	1.4	-0.3	0.2	0.5	-0.2	-0.2	0.6	0.3	0.6	0.5	0.1	0.6
S23	2.2	-1.4	3.1	3.1	1.8	3.0	3.2	1.7	3.0	2.8	2.6	1.1	0.6
Simple average	21.0	21.6	21.3	9.8	23.9	4.4	2.0	22.8	6.5	23.2	19.5	1.0	1.0

Notes: The description of each sector is given in Table 6.

Source: Own estimations using the GTAP database.

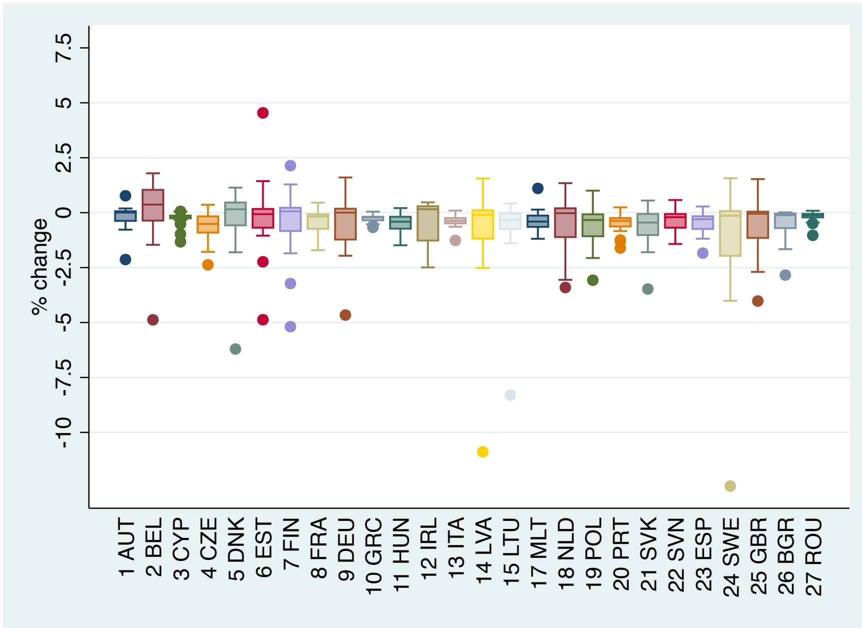
Table 12: Sectoral changes in export sales to Germany for selected countries, percentage changes

Sector:	AUT	BEL	CZE	FRA	HUN	ITA	NLD	ESP	SWE	GBR	CHN	JPN	KOR
S01	0.1	-1.0	0.7	0.1	0.5	0.2	-0.9	-0.1	0.2	-0.2	24.7	41.2	32.2
S02	-0.9	0.8	-0.9	-1.6	-1.3	-2.3	-0.7	-1.7	-0.4	-1.4	19.0	27.2	39.0
S03	0.0	1.7	-0.4	-0.2	-0.4	-0.5	0.2	-0.2	0.3	0.1	21.3	31.3	27.0
S04	-1.2	0.0	-1.1	-1.5	-1.7	-1.6	-1.0	-1.5	-1.5	-0.6	19.7	32.1	25.2
S05	-2.8	-0.5	-3.2	-3.7	-3.2	-3.7	-4.3	-3.3	-3.8	-4.6	10.8	17.1	13.6
S06	0.0	-0.1	0.3	0.1	0.6	0.3	-0.3	0.1	0.1	0.0	25.4	41.0	30.9
S07	-5.4	-3.7	-5.0	-7.9	-6.1	-6.5	-4.9	-7.0	-6.0	-4.5	31.0	121.2	37.4
S08	-0.1	1.0	-0.6	-0.4	-0.3	-0.6	0.2	-0.4	0.1	0.0	22.7	35.0	28.1
S09	-2.7	-2.5	-1.3	-4.1	-3.3	-4.6	-0.8	-4.1	-0.9	-2.5	9.9	11.5	7.7
S10	6.7	-3.4	8.7	7.3	8.3	7.6	4.6	9.9	7.7	11.4	38.6	60.9	47.6
S11	-0.1	0.2	1.0	0.9	1.1	1.2	-0.6	0.7	-0.7	0.7	22.0	37.2	29.1
S12	-11.0	-8.1	-5.6	-11.5	-11.4	-13.1	-6.5	-11.0	-11.4	-7.1	5.6	9.2	1.3
S13	-2.9	-2.5	-1.7	-3.5	-2.7	-3.9	-2.7	-3.5	-3.3	-2.5	14.8	11.1	10.7
S14	-6.7	-11.3	-5.2	-9.2	-8.7	-10.6	-3.8	-9.6	-10.0	-6.3	11.4	5.0	4.2
S15	-0.4	0.3	-0.5	-0.4	-0.3	-0.4	-0.1	-0.4	-0.4	-0.3	31.3	49.5	39.1
S16	-8.9	-3.2	-1.3	-2.1	-1.8	-1.7	-1.2	-4.8	-1.6	-1.2	41.7	60.6	70.5
S17	-5.4	-4.2	-4.1	-6.0	-5.9	-7.1	-3.6	-6.4	-2.9	-4.3	12.1	15.0	18.6
S18	-1.7	-2.5	-0.7	-2.0	-1.0	-2.6	-0.9	-2.2	0.0	-1.8	6.6	5.3	1.6
S19	-0.8	-0.3	-0.3	-0.6	-0.6	-0.9	-0.3	-0.7	-0.5	0.0	26.4	28.4	23.1
S20	-4.6	-2.4	-2.4	-4.4	-3.6	-4.5	-1.3	-4.1	-3.2	2.2	32.3	20.1	23.2
S21	0.0	0.0	0.0	-0.1	0.1	-0.3	0.0	-0.1	0.2	-0.1	-0.1	-0.5	-0.3
S22	-0.1	1.0	-0.7	-0.2	-0.6	-0.6	0.2	-0.1	0.2	0.1	0.2	-0.3	0.2
S23	0.6	-3.0	1.4	1.4	1.3	1.5	0.0	1.3	1.1	1.0	-1.1	-0.6	-1.0
Simple average	-2.1	-1.9	-1.0	-2.2	-1.8	-2.4	-1.3	-2.1	-1.6	-1.0	18.5	28.6	22.1

Notes: The description of each sector is given in Table 6.

Source: Own estimations using the GTAP database.

Figure 7: Sectoral output by EU countries, percentage changes



Source: Own estimations using the GTAP database.

Figure 8: Output by sector for all EU countries, percentage changes

Source: Own estimations using the GTAP database.

Table 13: CGE results on GDP, real income and welfare

	GDP index	Real Income	Welfare (per capita utility) % changes	Welfare (equivalent variation in US$ million)
Austria	0.01	0.01	0.10	530
Belgium	1.15	1.14	1.24	7,747
Cyprus	-0.27	-0.27	-0.27	-80
Czech Republic	-0.65	-0.62	-0.56	-1,582
Denmark	0.45	0.44	0.58	2,808
Estonia	0.21	0.19	0.37	144
Finland	0.23	0.25	0.37	1,113
France	-0.25	-0.28	-0.22	-7,743
Germany	0.18	0.17	0.32	12,527
Greece	-0.26	-0.25	-0.27	-1,134
Hungary	-0.67	-0.69	-0.68	-1,201
Ireland	0.35	0.31	0.43	1,860
Italy	-0.51	-0.51	-0.52	-12,381
Latvia	-0.06	-0.15	0.00	-2
Lithuania	-0.22	-0.22	-0.11	-59
Luxembourg	0.02	0.02	0.07	52
Malta	-0.47	-0.45	-0.46	-54
Netherlands	0.21	0.20	0.32	3,677
Poland	-0.29	-0.29	-0.17	-1,423
Portugal	-0.37	-0.41	-0.36	-1,040
Slovakia	-0.65	-0.61	-0.56	-843
Slovenia	-0.32	-0.37	-0.31	-216
Spain	-0.27	-0.32	-0.25	-4,291
Sweden	-0.02	-0.05	0.11	807
United Kingdom	0.01	-0.04	0.10	4,587
Bulgaria	-0.21	-0.28	-0.23	-197
Romania	-0.21	-0.28	-0.22	-629
Norway	0.10	0.20	0.30	2,979
China	0.57	0.63	0.56	81,813
Hong Kong	0.25	0.17	0.19	770
Japan	0.29	0.32	0.27	11,689
South Korea	0.73	0.72	0.70	12,508
Philippines	-0.05	-0.02	-0.05	-177
Other Asia Pacific	0.83	1.08	1.12	1,965
Taiwan	0.13	0.15	0.12	963
United States	-0.03	-0.04	-0.04	-10,474
Other OECD	0.02	0.09	0.05	3,407
Sub-Sah Africa exc. ZAF	0.00	0.12	0.06	1,501
Rest of the World	-0.12	-0.03	-0.09	-32,159
Total (World)	0.04	0.08	0.06	77,762

Source: Own estimations using the GTAP database.

Table 14: CGE results for the labour market, real wages and total employment changes for unskilled and skilled workers, percentage changes

	Changes in real wages				**Changes in total employment**			
	fixed labour supply		flexible lab. supply		fixed labour supply		flexible labour supply	
	unskilled	skilled	unskilled	skilled	unskilled	skilled	unskilled	skilled
AUT	0.04	0.08	0.05	0.08	0	0	0.01	0.02
BEL	1.02	1.02	1.08	1.09	0	0	0.22	0.22
CYP	-0.22	-0.17	-0.24	-0.19	0	0	-0.05	-0.04
CZE	-0.48	-0.32	-0.57	-0.43	0	0	-0.11	-0.09
DNK	0.45	0.48	0.47	0.50	0	0	0.09	0.10
EST	0.20	0.39	0.20	0.37	0	0	0.04	0.07
FIN	0.24	0.29	0.25	0.30	0	0	0.05	0.06
FRA	-0.17	-0.14	-0.21	-0.19	0	0	-0.04	-0.04
DEU	0.14	0.20	0.15	0.21	0	0	0.03	0.04
GRC	-0.20	-0.16	-0.24	-0.20	0	0	-0.05	-0.04
HUN	-0.55	-0.39	-0.62	-0.48	0	0	-0.13	-0.10
IRL	0.25	0.27	0.34	0.35	0	0	0.07	0.07
ITA	-0.36	-0.34	-0.46	-0.45	0	0	-0.09	-0.09
LVA	-0.16	0.04	-0.16	0.00	0	0	-0.03	0.00
LTU	-0.21	0.02	-0.21	-0.02	0	0	-0.04	0.00
LUX	0.14	0.12	0.13	0.12	0	0	0.03	0.02
MLT	-0.32	-0.21	-0.35	-0.25	0	0	-0.07	-0.05
NLD	0.26	0.29	0.28	0.31	0	0	0.06	0.06
POL	-0.28	-0.11	-0.32	-0.17	0	0	-0.06	-0.04
PRT	-0.29	-0.22	-0.35	-0.28	0	0	-0.07	-0.06
SVK	-0.53	-0.31	-0.63	-0.44	0	0	-0.13	-0.09
SVN	-0.28	-0.22	-0.31	-0.26	0	0	-0.06	-0.05
ESP	-0.21	-0.16	-0.24	-0.20	0	0	-0.05	-0.04
SWE	0.02	0.10	0.02	0.09	0	0	0.00	0.02
GBR	0.02	0.09	0.03	0.08	0	0	0.01	0.02
BGR	-0.35	-0.22	-0.36	-0.25	0	0	-0.07	-0.05
ROU	-0.27	-0.25	-0.30	-0.28	0	0	-0.06	-0.06
NOR	0.21	0.21	0.21	0.21	0	0	0.04	0.04
CHN	0.47	0.40	0.42	0.38	0	0	0.08	0.08
HKG	0.13	0.13	0.14	0.15	0	0	0.03	0.03
JPN	0.22	0.22	0.23	0.23	0	0	0.05	0.05
KOR	0.56	0.54	0.56	0.56	0	0	0.11	0.11
PHL	-0.02	-0.01	-0.07	-0.06	0	0	-0.01	-0.01
PNG	0.91	0.91	0.94	0.94	0	0	0.19	0.19
TWN	0.13	0.10	0.10	0.07	0	0	0.02	0.01
USA	-0.05	-0.05	-0.05	-0.06	0	0	-0.01	-0.01
OCD	-0.01	0.00	-0.01	0.00	0	0	0.00	0.00
SSA	-0.01	-0.03	-0.01	-0.03	0	0	0.00	-0.01
ROW	-0.14	-0.12	-0.15	-0.13	0	0	-0.03	-0.03

Source: Own estimations using the GTAP database.

Table 15: CGE results for the labour market, labour displacement and employment changes for unskilled labour in selected sectors, percentage changes

	labour displacement				Sectoral employment changes			
	fixed labour supply		flexible lab. supply		Unskilled, flexible labour supply			
	unskilled	skilled	unskilled	skilled	S02: Motor vehicles	S05: Clothing	S11: Metals	S14: Other manu-factures
AUT	0.68	0.51	0.68	0.50	0.16	-1.39	1.21	-3.64
BEL	0.82	0.64	0.76	0.58	0.97	0.71	1.25	-12.74
CYP	0.19	0.13	0.19	0.12	-1.61	-0.38	0.20	-0.72
CZE	0.96	0.63	0.92	0.60	-0.59	-2.45	1.09	-4.09
DNK	1.18	0.79	1.18	0.78	-1.60	-1.67	1.34	-9.78
EST	1.49	0.89	1.48	0.88	-1.01	-1.47	2.08	-9.65
FIN	1.28	0.89	1.28	0.88	-1.32	-4.27	3.48	-8.79
FRA	0.44	0.32	0.43	0.31	-1.25	-1.18	0.66	-2.45
DEU	1.22	0.95	1.21	0.95	-1.93	-2.78	2.14	-6.76
GRC	0.19	0.17	0.17	0.15	-0.74	-0.21	0.18	-0.35
HUN	0.59	0.47	0.55	0.43	-0.61	-0.61	0.80	-2.00
IRL	0.59	0.42	0.58	0.41	-3.18	-2.11	0.21	-6.06
ITA	0.31	0.26	0.26	0.22	-1.82	-0.34	0.43	-0.46
LVA	1.59	1.07	1.57	1.06	-1.03	-0.46	1.80	-13.68
LTU	1.17	0.66	1.16	0.66	-2.40	-1.29	1.15	-17.49
LUX	0.53	0.39	0.53	0.39	-0.52	-1.32	1.13	-1.78
MLT	0.54	0.37	0.51	0.35	-0.77	-1.15	0.42	-1.30
NLD	0.89	0.60	0.88	0.59	-0.80	-5.89	1.92	-5.61
POL	1.29	0.78	1.28	0.77	-0.25	-2.21	2.07	-5.32
PRT	0.47	0.35	0.44	0.33	-0.65	-0.57	0.57	-2.38
SVK	1.09	0.71	1.04	0.68	1.29	-1.35	0.61	-6.28
SVN	0.46	0.33	0.43	0.31	-2.02	-0.70	0.60	-1.26
ESP	0.47	0.37	0.45	0.35	-1.56	-0.44	0.70	-2.80
SWE	1.40	0.95	1.40	0.95	-0.62	-6.04	2.59	-16.68
GBR	0.88	0.62	0.88	0.62	-1.14	-3.40	1.84	-5.81
BGR	0.53	0.39	0.48	0.35	0.02	-1.37	-0.88	-5.75
ROU	0.25	0.18	0.23	0.16	-0.08	-1.16	0.27	0.05
NOR	0.80	0.74	0.80	0.74	-5.76	-7.03	4.08	-14.03
CHN	0.40	0.18	0.39	0.18	0.40	0.83	-1.00	1.20
HKG	0.23	0.18	0.23	0.18	-0.41	0.32	0.34	-1.18
JPN	0.38	0.32	0.37	0.31	1.82	-0.18	-0.44	0.18
KOR	0.61	0.35	0.58	0.33	2.48	0.36	-0.65	0.35
PHL	0.12	0.05	0.13	0.06	0.68	-0.07	-0.79	0.00
PNG	0.59	0.34	0.53	0.30	0.78	0.46	2.15	0.96
TWN	0.25	0.16	0.24	0.16	0.27	0.10	0.12	0.09
USA	0.07	0.06	0.07	0.05	-0.15	-0.07	0.08	0.08
OCD	0.10	0.07	0.09	0.06	-0.21	-0.21	-0.58	0.15
SSA	0.09	0.04	0.08	0.03	-0.39	-0.14	-0.26	-0.08
ROW	0.16	0.09	0.13	0.08	-0.33	-0.45	-0.17	-0.30

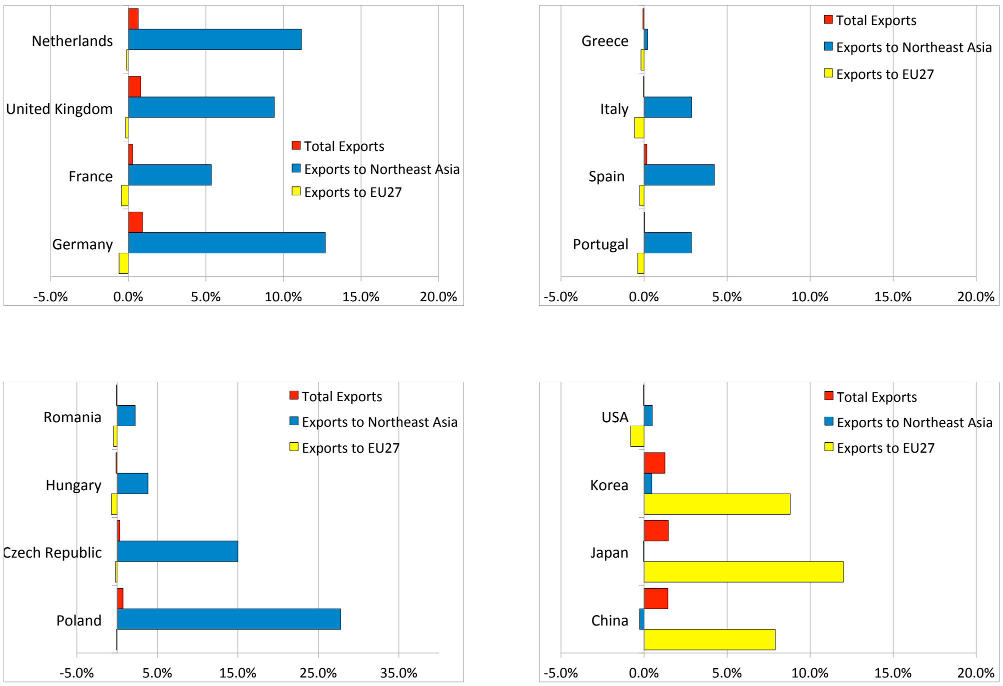
Notes: labour displacement is the weighted standard deviation of the sectoral changes. Source: Own estimations using the GTAP database.

Table 16: CGE results on CO2 emissions

	CO2 emission changes (MT)	CO2 emission % changes	Benchmark CO2 levels (projections in 2030)	share in 2030 projections
Austria	0.12	0.15	80	0.1%
Belgium	0.82	0.65	127	0.2%
Cyprus	-0.05	-0.35	14	0.0%
Czech Republic	-0.64	-0.42	152	0.2%
Denmark	0.17	0.18	92	0.1%
Estonia	-0.04	-0.22	20	0.0%
Finland	0.03	0.04	71	0.1%
France	-0.73	-0.16	455	0.7%
Germany	-0.05	-0.01	729	1.1%
Greece	-0.35	-0.31	113	0.2%
Hungary	-0.22	-0.41	54	0.1%
Ireland	0.10	0.18	60	0.1%
Italy	-1.68	-0.39	426	0.7%
Latvia	-0.04	-0.21	18	0.0%
Lithuania	-0.09	-0.50	19	0.0%
Luxembourg	-0.01	-0.03	18	0.0%
Malta	-0.01	-0.20	4	0.0%
Netherlands	0.33	0.15	213	0.3%
Poland	-5.03	-1.25	399	0.6%
Portugal	-0.10	-0.15	68	0.1%
Slovakia	-0.28	-0.52	54	0.1%
Slovenia	-0.05	-0.25	20	0.0%
Spain	-1.04	-0.27	378	0.6%
Sweden	0.03	0.05	72	0.1%
United Kingdom	-0.25	-0.04	666	1.0%
Bulgaria	-0.08	-0.12	72	0.1%
Romania	-0.23	-0.19	119	0.2%
Norway	-0.13	-0.14	94	0.1%
China	85.68	0.30	28,418	44.1%
Hong Kong	1.67	0.93	181	0.3%
Japan	1.42	0.13	1,127	1.7%
South Korea	2.49	0.32	787	1.2%
Philippines	-0.16	-0.10	169	0.3%
Other Asia Pacific	0.52	1.09	48	0.1%
Taiwan	0.15	0.03	552	0.9%
United States	-7.76	-0.10	7,963	12.4%
Other OECD	-0.45	-0.03	1,549	2.4%
Sub-Sah Africa exc. ZAF	-0.25	-0.04	575	0.9%
Rest of the World	-25.98	-0.14	18,469	28.7%
Total (World)	47.79	0.074	64,446	100%

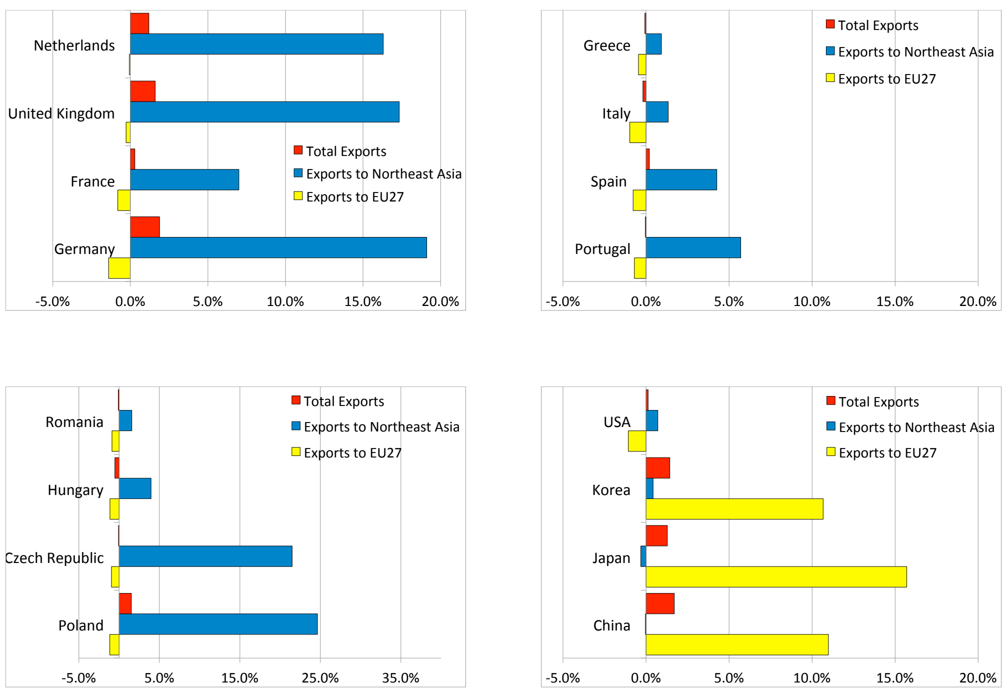
Source: Own estimations using the GTAP database.

Figure 9: Benchmark year 2015, trade flows after opening the NSR: percentage changes in exports by selected countries



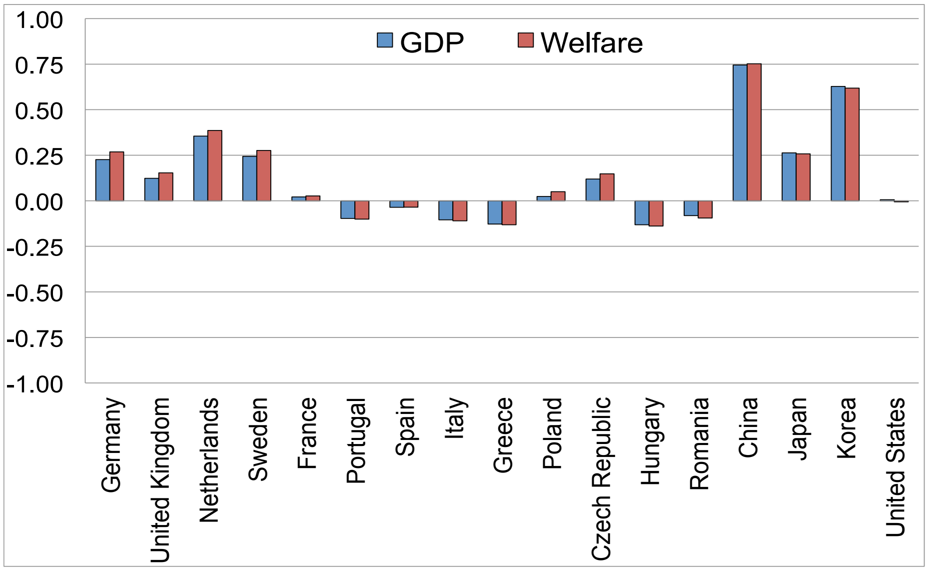
Notes: The horizontal scale for the Eastern EU countries is different than the scale for the other regions. Source: Own estimations using the GTAP database.

Figure 10: Benchmark year 2050, trade flows after opening the NSR: percentage changes in exports by selected countries



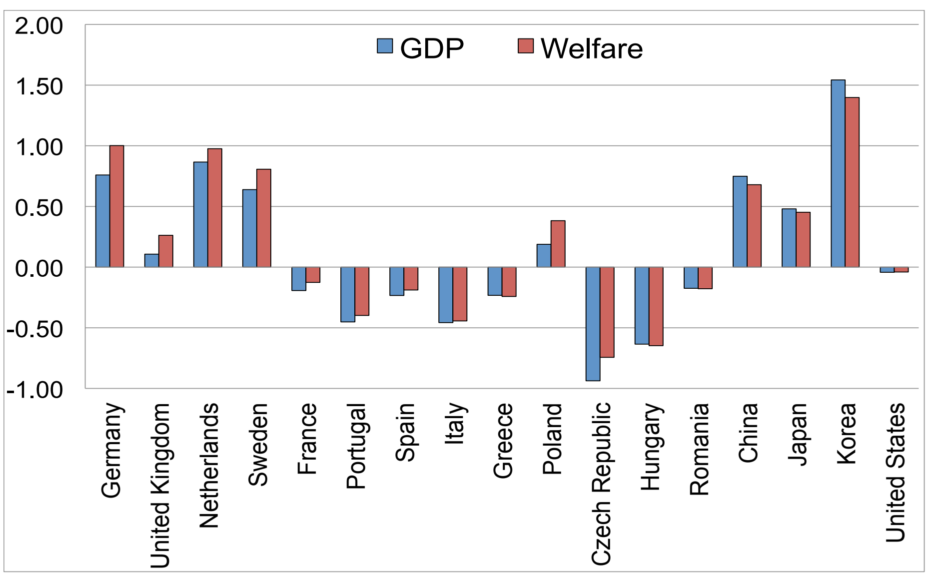
Notes: The horizontal scale for the Eastern EU countries is different than the scale for the other regions. Source: Own estimations using the GTAP database.

Figure 11: Benchmark year 2015, GDP and welfare changes associated with the opening of the NSR, percentage changes



Source: Own estimations using the GTAP database.

Figure 12: Benchmark year 2050, real income and GDP changes associated with the opening of the NSR, percentage changes



Source: Own estimations using the GTAP database.

Table 17: Benchmark year 2015, CGE results on GDP, real income, welfare, and CO2 emission changes

	GDP index	Real Income	Welfare (per capita utility) % changes	Welfare (equivalent variation in US$ million)	CO2 emission % changes
Austria	0.19	0.20	0.21	731	0.11
Belgium	1.33	1.26	1.28	5,513	0.94
Cyprus	-0.05	-0.03	-0.06	-12	-0.14
Czech Republic	0.12	0.12	0.15	242	0.03
Denmark	0.76	0.76	0.77	2,187	0.30
Estonia	0.48	0.46	0.50	102	-0.36
Finland	0.47	0.53	0.51	1,097	0.15
France	0.02	0.03	0.03	644	0.00
Germany	0.23	0.25	0.27	8,187	0.10
Greece	-0.13	-0.10	-0.13	-305	-0.35
Hungary	-0.13	-0.13	-0.14	-170	-0.13
Ireland	0.85	0.79	0.84	2,032	0.44
Italy	-0.10	-0.10	-0.11	-1,930	-0.14
Latvia	0.11	0.07	0.11	28	0.22
Lithuania	-0.02	-0.04	-0.01	-2	0.05
Luxembourg	0.08	0.12	0.12	56	0.11
Malta	-0.06	-0.04	-0.07	-5	-0.10
Netherlands	0.35	0.36	0.39	2,741	0.35
Poland	0.02	0.02	0.05	243	-0.66
Portugal	-0.10	-0.10	-0.10	-204	-0.05
Slovakia	0.02	0.01	0.04	39	-0.07
Slovenia	-0.10	-0.11	-0.11	-45	-0.12
Spain	-0.04	-0.04	-0.04	-446	-0.12
Sweden	0.24	0.27	0.28	1,277	0.32
United Kingdom	0.12	0.13	0.15	4,003	0.05
Bulgaria	-0.25	-0.25	-0.27	-116	-0.30
Romania	-0.08	-0.10	-0.09	-149	-0.09
Norway	0.23	0.43	0.36	1,343	0.06
China	0.75	0.84	0.75	46,917	0.44
Hong Kong	0.61	0.52	0.55	1,277	0.79
Japan	0.26	0.31	0.26	9,761	0.15
South Korea	0.63	0.68	0.62	7,417	0.34
Philippines	0.24	0.27	0.23	413	0.17
Other Asia Pacific	0.24	0.40	0.35	194	0.19
Taiwan	0.18	0.23	0.18	871	0.07
United States	0.01	0.02	0.00	-531	-0.05
Other OECD	0.06	0.11	0.07	1,949	-0.02
Sub-Sah Africa exc. ZAF	0.08	0.23	0.15	1,120	0.02
Rest of the World	0.03	0.10	0.05	7,333	-0.04
Total (World)	0.16	0.21	0.17	103,800	0.12

Source: Own estimations using the GTAP database.

Table 18: Benchmark year 2050, CGE results on GDP, real income, welfare, and CO_2 emission changes

	GDP index	Real Income	Welfare (per capita utility) % changes	Welfare (equivalent variation in US$ million)	CO2 emission % changes
Austria	0.45	0.49	0.61	5,269	0.26
Belgium	2.14	1.81	2.06	21,899	1.11
Cyprus	-0.17	-0.16	-0.19	-83	-0.29
Czech Republic	-0.94	-0.75	-0.74	-4,524	-0.59
Denmark	0.53	0.52	0.73	6,466	0.37
Estonia	0.47	0.55	0.82	729	-0.19
Finland	0.32	0.32	0.50	2,220	0.25
France	-0.19	-0.16	-0.13	-7,289	-0.10
Germany	0.76	0.78	1.00	60,772	0.53
Greece	-0.23	-0.21	-0.24	-1,588	-0.17
Hungary	-0.64	-0.64	-0.65	-2,598	-0.33
Ireland	0.63	0.58	0.73	5,934	0.21
Italy	-0.46	-0.40	-0.44	-17,105	-0.33
Latvia	-0.06	-0.11	0.09	119	-0.04
Lithuania	-0.25	-0.31	-0.07	-96	-0.67
Luxembourg	0.21	0.30	0.30	425	0.17
Malta	-1.64	-1.37	-1.50	-426	-0.64
Netherlands	0.87	0.77	0.98	19,583	0.49
Poland	0.19	0.17	0.38	7,381	-0.06
Portugal	-0.45	-0.40	-0.40	-1,879	-0.27
Slovakia	-0.99	-0.84	-0.84	-2,400	-0.61
Slovenia	-0.15	-0.10	-0.11	-193	-0.08
Spain	-0.23	-0.23	-0.19	-4,913	-0.24
Sweden	0.64	0.62	0.81	9,769	0.59
United Kingdom	0.11	0.11	0.26	24,040	0.09
Bulgaria	-1.95	-1.69	-1.84	-3,332	-0.58
Romania	-0.17	-0.23	-0.18	-1,358	-0.16
Norway	0.29	0.32	0.49	10,215	-0.07
China	0.75	0.63	0.68	187,235	0.48
Hong Kong	0.17	0.12	0.14	839	0.48
Japan	0.48	0.52	0.45	26,379	0.21
South Korea	1.54	1.29	1.40	30,122	0.70
Philippines	-0.98	-0.77	-0.95	-6,698	-0.80
Other Asia Pacific	0.43	0.57	0.61	3,170	0.48
Taiwan	-0.30	-0.25	-0.32	-4,449	-0.27
United States	-0.04	-0.02	-0.04	-20,371	-0.14
Other OECD	0.02	0.11	0.06	9,421	-0.02
Sub-Sah Africa exc. ZAF	-0.02	0.12	0.03	3,608	-0.08
Rest of the World	-0.24	-0.07	-0.20	-199,051	-0.29
Total (World)	0.08	0.13	0.11	157,243	0.09

Source: Own estimations using the GTAP database.