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 Northwestern Europe. This represents a sizeable reduction in shipping distances and a decrease in the average transportation days by around one-third compared to the usual Southern Sea Route. We examine the economic impact of the opening of the Northern Sea Route. This includes a dramatic 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. The estimated redirection of trade has major geopolitical implications linked to both a drop in traffic on the Southern Sea Route (i.e. Suez) and heavy traffic along ecologically sensitive Arctic routes.
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1 Introduction

Arctic ice caps have been melting as a result of global warming. The phenomenon has been well documented (Rodrigues, 2008; Kinnard *et al.*, 2011), and there is broad agreement that the ice caps in Greenland and Antarctica have been melting at an ever-quicker pace since 1992 (Shepherd *et al.*, 2012; Kerr, 2012). 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 Northwestern Europe through the Arctic Ocean (see Figure 1). In

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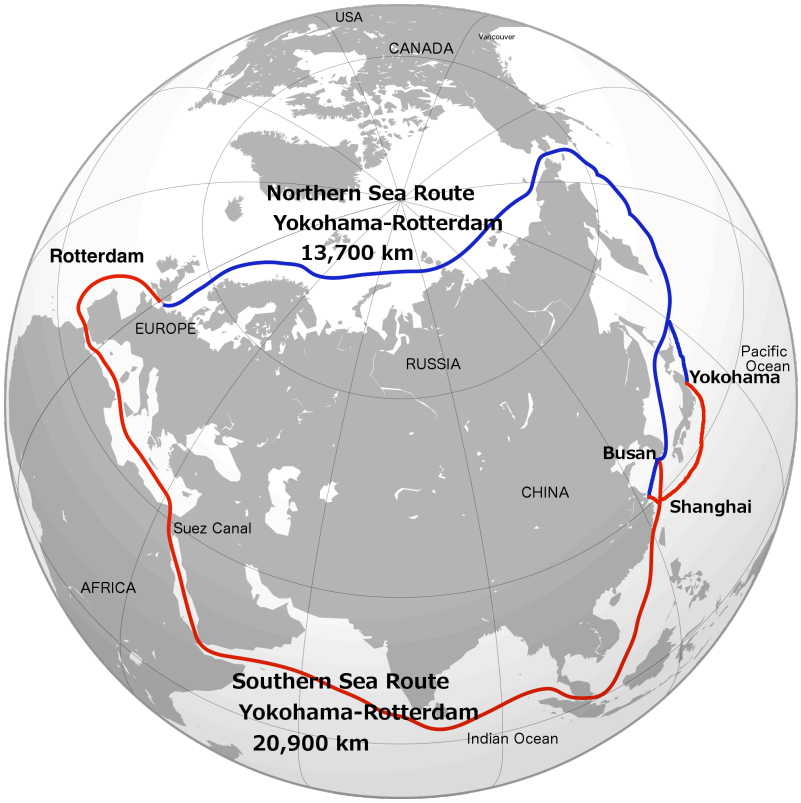
practical terms this represents a reduction in the average shipping distances and days of transportation of around one third with respect to the currently used Southern Sea Route (SSR). These reductions translate not only into fuel savings and overall transport costs, but also to significant transport 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 for four or five months a year during summer and a number of ships have already used the route. Until 2011 there was still controversy about the feasibility of the commercial use of the NSR. However, the ever-quicker melting pace found by Shepherd *et al.* (2012), Kerr (2012) and Slezak (2013) has broadened the consensus in favor of its likely commercial use in the near future. For instance, Verny and Grigentin (2009) estimate that within 10 years this shipping route could be fully operational all-year round. As a consequence, Asia's big 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 and heightened political interest on 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, 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 are solved, so the NSR is fully operationally all year round. In practical terms this implies that all commercial shipping between North East Asia and Northern Europe will use the NSR instead of the SSR. Since this process will take years, we also assume that the economic adjustment pattern will be gradual and stretching over several years until 2030.[1]

Our economic analysis follows a three-step process. In the first step we re-estimate 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 and the total amount of CO2 emissions.

We find that the NSR reduces shipping distances and time between Northwestern Europe and Northeast Asia by about one third. This is translated into average trade cost reductions of around 5% of the value of goods sold. These overall trade costs 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 t For instance, 13.8% 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 15000 commercial ships crossed the Suez Canal yearly between 2008 and 2012, the re-routing of ships through the NSR will represent about 10000 ships crossing the Arctic yearly.[2] 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 big economic zones also results in a significant diversion of trade. The bilateral trade flows between Northeast Asia and Northwestern Europe significantly increase at the expense of less

[1] However, as explained below, the use of 2030 as our benchmark years is mainly for illustration purposes and the use of a particular year does not affect our main economic results.

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

trade with other regions. In particular, there is a sizable reduction in intra-European trade, with less trade between Northwestern Europe with South and Eastern Europe. Bilateral exports from Northwestern Europe (Germany, France, The Netherlands and the UK) to/from Northeastern Asia (China, Japan and South Korea) increase significantly, while South European exports remain flat. 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 exports changes for Hungary and Romania.

The changing opportunities for trade translate into macroeconomic impacts as well: GDP is estimated to increase modestly in the countries that benefit directly from the NSR . Northeast Asia experiences the biggest gains, while Northwestern Europe has less pronounced GDP increases (with the exemption of France). On the other hand, most South and Eastern European countries experience GDP and welfare decreases. Hence, the disruption in intra-EU trade and regional production value chains caused by the opening of the NSR, is affecting negatively the South and Eastern EU members states. For the affected countries 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 (see for example Francois (2000), Francois *et al.* (2005), and Francois, Manchin, Norberg, Pindyuk and Tomberger (2013)). However, we do not find any sizable effects on labour market outcomes and moreover, the expected gradual opening of the NSR also means that there will be no large short-term labour adjustment shocks.

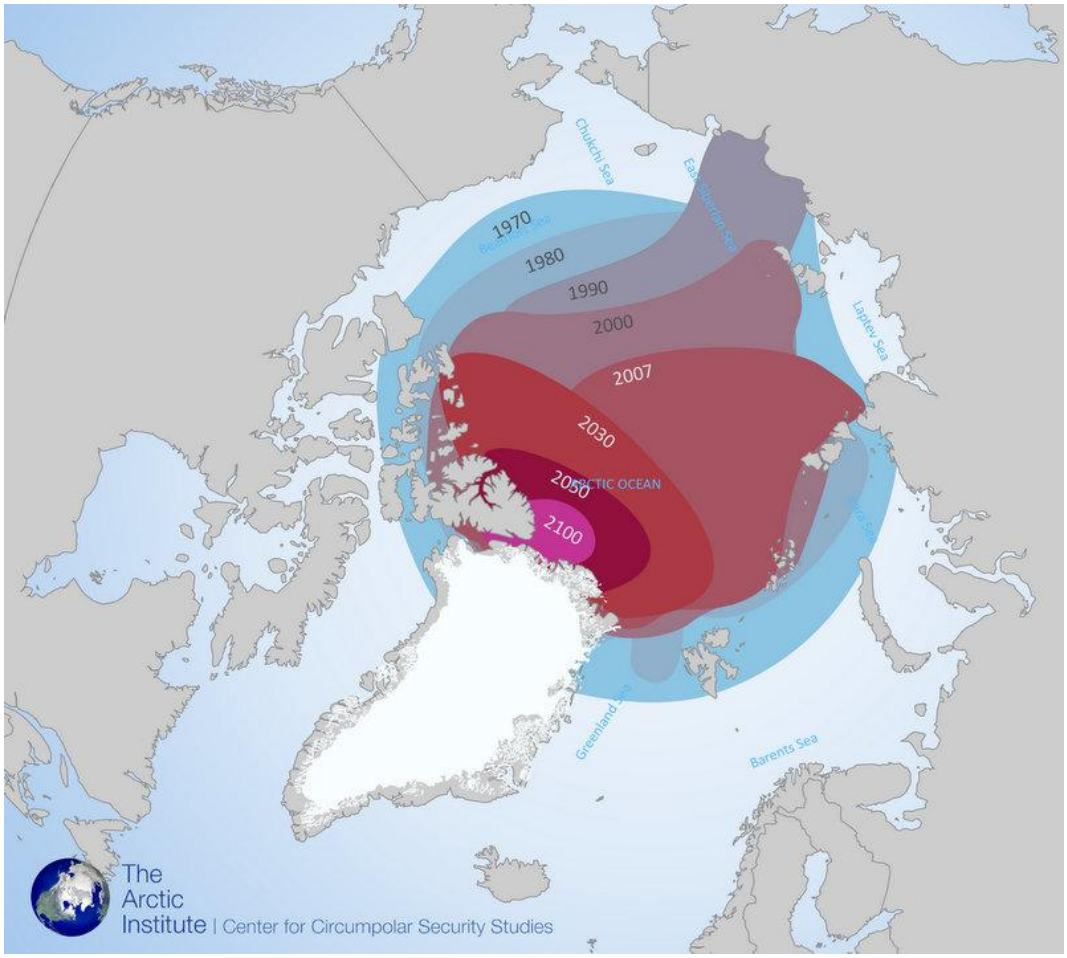
Finally, we also estimate the impact of the NSR on changes in CO2 emissions. We find that although the much shorter shipping distances will reduce the emissions associated with water transport, these gains are all but offset by a combination of higher volumes traded between Northeast Asia and Northwestern Europe, and a shift in emission-intensive production to East Asia.

2 The commercial feasibility of the North 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. As mentioned before there is ample scientific evidence of the melting of the Arctic ice cap (Rodrigues, 2008; Kinnard *et al.*, 2011; Shepherd *et al.*, 2012; Kerr, 2012). In addition, the National Aeronautics and Space Administration (NASA) research suggests that multi-year ice, which is the oldest and thickest Arctic sea ice is disappearing at a faster rate than the younger and thinner ice, and that the distribution of the remaining ice is not uniform, but more concentrated in the Canadian Archipelago and Greenland (Humpert and Raspotnik, 2012). Both elements 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.

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.

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 limited number of ships have already used the NSR during summer months[3], 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

[3]Most of them with assistance from Atomflot, the operator of Russia's nuclear icebreaker fleet.

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 stakeholders to develop the NSR, it is expected that these logistic limitations will be gradually overcome in the near future.[4]

The uncertainties on 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, in addition, are also directly related and reinforce each other. In particular, a quicker pace of melting will also make it 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 full 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. We needed to choose a benchmark year mainly for reporting reasons, since we expect to have quantitatively similar results if we used another benchmark year, either an earlier one (e.g. 2025) or later ones (e.g. 2040 or 2050). The main difference between using different benchmark years is that the path of adjustment will be directly proportional to the exact date for which the NSR becomes fully operational. 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 substitute to the SSR.

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).[5] However, these measures

[4]For instance, Russia created in March 2013 a Federal State Institution 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.

[5]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

use the 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.

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-neighboring 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.[6] 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' capitals using their major ports. For example we estimate the trade distance between China and The Netherlands as the land distance from Beijing (capital city) to Shanghai (main seaport), plus the water distance from Shanghai to Rotterdam using either the SSR or the NSR, plus the land distance between Rotterdam (main seaport) and Amsterdam (capital city). For landlocked countries[7] we assume that a port in a neighboring country is used, so

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.

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

[7]These are countries that do not have direct access to an ocean or an ocean-accessible water way, and thus must rely upon neighboring 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, Serbia, Slovakia, Swaziland, Switzerland, Tajikistan, Turkmenistan, Uganda, Uzbekistan, Vatican City, Zambia, Zimbabwe.

distance between a landlocked country and a trading partner with access to water is obtained by combining the landlocked country's land distance (from CEPII) to the next major port in a neighboring country and water distances from that port to different trading partners (from AtoBviaC). For example distance between Austria and Nepal 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.

For the new distances related to the opening up of the NSR, we use the estimates by Lasserre and Pelletier (2011) so instead of 20900 km from Rotterdam to Yokohama (using Suez) we now have 13700 km (using the NSR). Since only some countries will be economically affected by the opening of the NSR, we only estimate the new shorter distances to Europe for a selected number of Asian and Oceanian countries.[8] We also take into account shipping distance asymmetries. Due to sea currents, shipping distances from country A to country B are not the same as 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 NSR (see Table 7 in the Appendix). 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 Northeast 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 34% from Japan to North European countries, while the same figure is around 27% for South Korea, 22% for China and 14% 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 equator. For instance, the shipping distances from the Philippines, Papua New Guinea and Australia 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 on 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 tool in international trade and it has been a very pow-

[8] 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	19,723	15,217	-23%
Japan	Netherlands	9,303	20,922	13,718	-34%
Japan	Belgium	9,464	20,894	13,759	-34%
Japan	Germany	8,928	21,458	14,224	-34%
Japan	United Kingdom	9,574	20,703	13,499	-35%
South Korea	Netherlands	8,573	20,405	14,751	-28%
South Korea	Belgium	8,722	20,378	14,792	-27%
South Korea	Germany	8,140	20,941	15,257	-27%
South Korea	United Kingdom	8,875	20,186	14,532	-28%
Taiwan	Netherlands	9,457	18,750	16,150	-14%
Taiwan	Belgium	9,587	18,722	16,190	-14%
Taiwan	Germany	8,959	19,286	16,655	-14%
Taiwan	United Kingdom	9,790	18,531	15,930	-14%

Sources: Great-circle distances taken from the GeoDist database from CEPII. SSR and NSR distances are own estimations based on data from AtoBviaC and Lasserre and Pelletier (2011).

erful instrument to predict bilateral trade flows based mainly on the economic sizes of bilateral partners (using GDP measures), the physical distance between them and a set of variables that account for other factors that may facilitate or mitigate trade (e.g. common language, free trade agreements, colonial ties). An econometrically estimated gravity model provides a measure of how much the physical distance between partners hinders bilateral trade. In other words, it estimates empirically how much the distance between two trading partners can be associated with the *trade costs* these countries face. When we substitute the current shipping distances using the SSR with the new NSR distances, we obtain a measure of how much the current trade costs will be reduced by the shorter shipping distances associated with the NSR.[9]

The gravity model of trade was first used by Nobel prize winner Jan Tinbergen in 1962, and the particular estimation techniques and specific variables included in the model (besides indicators of size and distance) have changed over time. As our main specification we use the model proposed by Anderson and van Wincoop (2003)

[9] A detailed explanation of the gravity model estimations and tables summarizing the main results are shown in the Supplementary Materials section.

who incorporate "multilateral resistance" terms into the main gravity equation.[10] We also use the state-of-the-art estimation technique, which is a Poisson pseudo-maximum likelihood (PPML) specification (Santos Silva and Tenreyro, 2006, 2011), such that:

$$T_{ijs} = exp\left[\beta_0 + \beta_1 lnG_i + \beta_2 lnG_j + \beta_3 lnD_{ij} + \gamma \mathbf{C_{ijs}}\right] \eta_{ijs} \tag{1}$$

where T_{ijs} represents volume of trade from country i to country j in sector s, G is the vector of exporter (i) and importer (j) fixed effects –which include time fixed effects and implicitly also GDP/expenditures and multilateral resistance terms– while D_{ij} denotes the distance between the two countries (i.e. the variable we change in our estimations to account for different shipping routes). Finally, C is a matrix of control variables and γ is their corresponding vector of estimated coefficients.[11] Finally, η_{ijs} are the error terms.

We first use our new land-water distances estimated previously for the SSR as the distance measure (D_{ij}) –instead of using the commonly used CEPII's bilateral distances. In a second step, we substitute the SSR distances with the shorter NSR distances for the relevant regions (i.e. we substitute D_{ij}). Using the previously estimated β_3 coefficients we can assess how much the decrease in the distance variable (D_{ij}) translates into overall trade cost reductions.

In turn, this overall cost decrease is separated between the purely transport related component (using as reference the current transport costs structure from the GTAP database) and the residual trade cost component (which is the difference between the overall cost minus the transport cost). Thus, distance reductions associated with the NSR are separated into two main effects. First, the shorter shipping distances using the NSR are directly translated into fuel savings and overall transport cost reductions. These transport costs reductions are equal for all industries and range between 10 to 35% depending on the trading partners (see Table 2). Second, reduced distances also yield significant transport time savings that can effectively create new supply chains in certain industries (Hummels and Schaur, 2012), these savings are represented by bilateral and sector-specific trade cost equivalences between industries and partners (see Table 3).

[10] However –as explained below– we also use different model specifications to test the robustness of our results.

[11] As controls we use standard variables: dummies for having colonial ties, country contiguity, access to sea, average tariffs, bilateral free trade agreements, and common language.

Table 2: Transport cost reductions for selected countries.

From:	To:	% reduction	From:	To:	% reduction
BEL	CHN	22.3	CHN	BEL	21.09
BEL	JPN	34.1	CHN	DEU	20.89
BEL	KOR	27.4	CHN	GBR	21.61
BEL	TWN	13.5	CHN	NLD	21.37
DEU	CHN	22.2	JPN	BEL	34.02
DEU	JPN	33.7	JPN	DEU	33.59
DEU	KOR	27.1	JPN	GBR	34.67
DEU	TWN	13.6	JPN	NLD	34.31
GBR	CHN	22.8	KOR	BEL	26.24
GBR	JPN	34.8	KOR	DEU	25.90
GBR	KOR	28.0	KOR	GBR	26.79
GBR	TWN	14.0	KOR	NLD	26.51
NLD	CHN	22.6	TWN	BEL	12.29
NLD	JPN	34.4	TWN	DEU	12.32
NLD	KOR	27.7	TWN	GBR	12.74
NLD	TWN	13.9	TWN	NLD	12.59

Source: Own estimations.

Table 3: 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	2.41	5.57	0.28	CHN	BEL	2.57	5.92	0.30
BEL	JPN	4.18	9.58	0.49	CHN	DEU	2.55	5.88	0.30
BEL	KOR	3.09	7.10	0.36	CHN	GBR	2.64	6.09	0.31
BEL	TWN	1.35	3.12	0.16	CHN	NLD	2.61	6.01	0.30
DEU	CHN	2.39	5.51	0.28	JPN	BEL	4.20	9.62	0.50
DEU	JPN	4.12	9.43	0.49	JPN	DEU	4.14	9.47	0.49
DEU	KOR	3.04	7.00	0.36	JPN	GBR	4.30	9.83	0.51
DEU	TWN	1.35	3.13	0.16	JPN	NLD	4.24	9.71	0.50
GBR	CHN	2.48	5.72	0.29	KOR	BEL	3.24	7.46	0.38
GBR	JPN	4.28	9.79	0.51	KOR	DEU	3.21	7.38	0.38
GBR	KOR	3.16	7.27	0.37	KOR	GBR	3.33	7.65	0.39
GBR	TWN	1.40	3.25	0.16	KOR	NLD	3.29	7.55	0.39
NLD	CHN	2.45	5.65	0.29	TWN	BEL	1.49	3.46	0.17
NLD	JPN	4.22	9.67	0.50	TWN	DEU	1.50	3.49	0.17
NLD	KOR	3.12	7.18	0.37	TWN	GBR	1.55	3.59	0.18
NLD	TWN	1.38	3.21	0.16	TWN	NLD	1.53	3.55	0.18

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.

It is important to note that an additional contribution of our study is that these improved distance estimations yield more accurate estimations of the bilateral trade and transportation costs elasticities derived from standard gravity models.

Finally, we also use alternative specifications of the gravity model to check for the robustness of our results. These include additional controls for the endogeneity of free trade agreements.

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 phenomenon that affects several countries at once, it will create inter-related shocks between different trading economies. 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 to analyse such global issues.[12] In this context, our CGE model can analyse how macroeconomic variables change with respect to a benchmark global economy projection in the year 2030. The model provides information on the impact on bilateral trade flows, socioeconomic indicators, transport related pollution levels, and overall CO2 emissions.

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 on a large number of markets. They provide an explicit and detailed treatment of international trade and transport margins, while bilateral trade is handled via CES (constant elasticity of demand) preferences for intermediate and final goods.[13] 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. For example, CGE models are routinely used in the fields of international trade, economic integration and climate change. The opening of the NSR, therefore, fits within the analytical scope of CGE models since

[12] See for instance, Schmalensee *et al.* (1998), **?**, Peng (2011); Auffhammer and Steinhauser (2012).

[13] 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). However, 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 will be found using a wider set of trade models (e.g. the Eaton-Kortum model), although the production and welfare implications can be different between both sets of models. See Francois, Manchin and Martin (2013) for a more technical discussion of demand systems and different market structures.

it implies a very sizable shock to the world trade system that will affect a large set of countries simultaneously.[14]

The particular model we use is a modified version of a standard GTAP-class CGE model[15] However, our specific CGE model incorporates monopolistic competition instead of perfect competition with constant returns to scale (Francois, Manchin and Martin, 2013), and CO2 emissions linked to production, consumption and trade.[16]

To assess the global general equilibrium effects of the commercial use of the North-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 (International Institute for Applied Systems Analysis (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 CO2 emissions from production and international transport.[17] We aggregate the 57 GTAP sectors into 23 sectors (and the 129 regions into 39 country/regions (see Table 5 and Table 6 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 scenario with no NSR shipping) compared with the counterfactual scenario where we allow bilateral trade to move through the NSR. In this counterfactual scenario, thus, 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.[18] 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,

[14]It is important to note that recent quantitative trade models –summarized by Costinot and Rodríguez-Clare (2013)– are not able to handle the current exercise. These micro-theory based econometric models are highly stylized quantification methods, that however, are not capable of dealing with detailed analysis of global trade issues. Thus, even though these models are well grounded in recent micro-economic theory, their scope is very limited in terms of actual analysis. In particular, these models simply cannot be used to address the current exercise, since 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 in nature. These are issues central to the evaluation of the economic and environmental effects of the NSR that can only be tackled using a CGE model.

[15]The main characteristics and references to the standard GTAP model can be found at: www.gtap.agecon.purdue.edu/models/current.asp. Also see Hertel (2013) for a more detailed discussion.

[16]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.

[17]GTAP is the standard basic data used in most CGE models. See Narayanan *et al.* (2012) for documentation on the GTAP 8 database, and Hertel (2013) on the full database project.

[18]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 trade costs.

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.

5.1 Trade effects

Once we run the counterfactual simulation we obtain global and bilateral trade changes. This 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 4.59%, but global trade volumes increase by 2.44%. Although these global trade volume changes are not radically high, they are completely concentrated in trade changes between Northeast 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 6%.

Table 4 shows the bilateral trade changes of the main for Northeast Asian countries. We can observe here the significant changes in exports and import values of the three main Asia countries that benefit from the NSR: China, Japan, and South Korea. First, we observe how Northwestern countries increase significantly 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. On the other hand, exports to Northeast Asia barely change for the group of Southern European countries: Portugal, Spain, Italy, Greece, Malta and Cyprus. An interesting case is Eastern Europe, where some countries closer to the North increase their exports to Northeastern Asia (e.g. Czech Republic, Estonia, Latvia, Lithuania, Poland and Slovakia), while others have no significant 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 huge increase in bilateral trade between two relatively big economic zones is translated into a significant diversion of trade –i.e. the bilateral trade flows between Northeast Asia and Northwestern Europe significantly increase at the expense of less trade with other regions. The main diversion effect is that there is a sizable reduction in intra-European trade, with less trade between Northwestern Europe with South and Eastern Europe. Figure 3 shows these trade diversion patterns.

Table 4: Northeast Asia, changes in trade values for goods and services, percentage changes

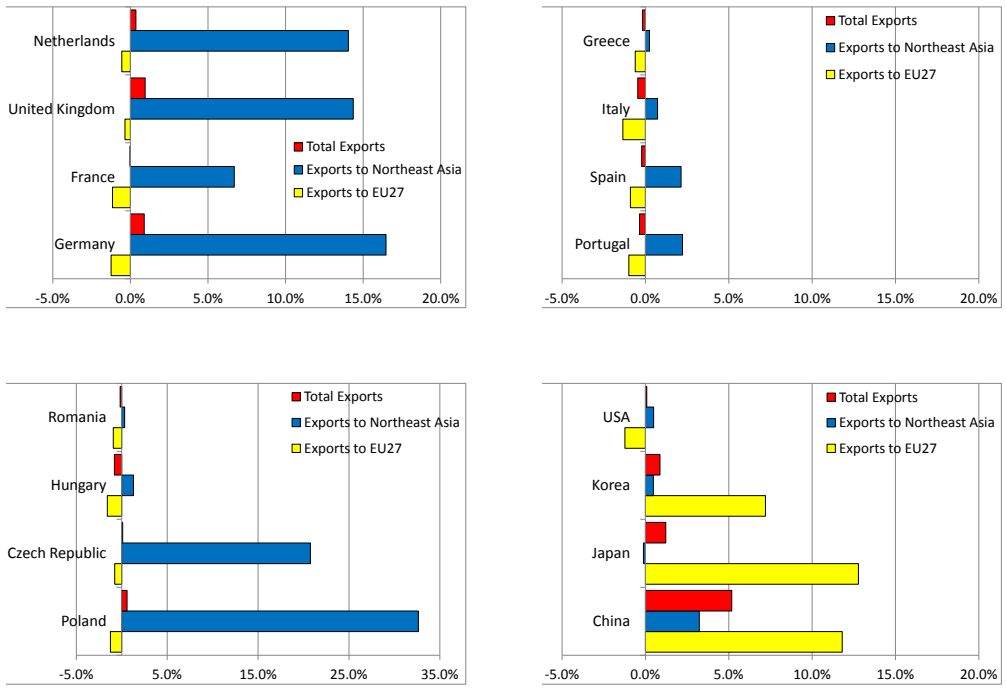
	China		Japan		South Korea	
	exports	imports	exports	imports	exports	imports
1 AUT	18.29	15.08	14.12	27.56	11.42	16.00
2 BEL	17.68	20.49	20.31	18.15	18.70	16.86
3 CYP	2.26	0.43	-0.76	0.39	-0.84	0.02
4 CZE	14.64	22.83	16.70	24.12	10.42	21.24
5 DNK	17.68	12.50	4.91	19.72	6.35	14.05
6 EST	16.30	20.29	13.76	41.60	12.60	18.30
7 FIN	13.60	13.90	16.58	25.90	11.10	17.89
8 FRA	6.28	4.95	10.96	16.88	5.76	8.60
9 DEU	14.06	15.82	17.05	22.42	8.64	18.85
10 GRC	2.83	0.31	-0.42	0.28	-0.17	0.10
11 HUN	0.29	1.68	-2.26	1.04	-2.27	0.61
12 IRL	10.38	12.56	7.37	22.17	6.68	22.54
13 ITA	3.25	0.97	-1.31	0.31	-1.26	0.51
14 LVA	19.47	29.88	10.48	28.58	9.81	27.33
15 LTU	17.55	45.38	11.38	29.80	13.92	27.28
16 LUX	9.15	11.27	3.16	2.61	0.22	7.14
17 MLT	1.47	1.97	-0.90	0.68	-0.61	1.45
18 NLD	14.08	14.94	14.13	17.87	13.32	18.14
19 POL	17.43	35.30	18.69	25.80	11.48	19.63
20 PRT	2.88	2.32	5.46	3.32	2.67	1.80
21 SVK	13.49	17.91	16.63	24.62	13.18	21.21
22 SVN	1.07	1.21	-1.11	0.55	-1.34	0.24
23 ESP	4.16	1.51	7.93	7.11	3.21	3.40
24 SWE	13.67	14.42	19.51	25.73	8.99	16.52
25 GBR	18.63	15.66	17.71	16.49	6.78	17.83
26 BGR	2.12	0.67	-0.87	0.54	-1.32	0.49
27 ROU	1.65	0.31	-1.06	0.84	-1.32	0.61
28 NOR	14.73	16.70	14.49	21.31	3.50	11.62
29 CHN	0.00	0.00	0.13	3.49	0.56	3.41
30 HKG	1.97	0.91	-0.56	0.56	0.02	0.28
31 JPN	3.49	0.13	0.00	0.00	0.37	-0.39
32 KOR	3.41	0.56	-0.39	0.37	0.00	0.00
33 PHL	2.62	2.09	-0.12	1.50	-0.25	2.03
34 PNG	-0.21	0.95	-1.82	2.42	-0.73	-0.44
35 TWN	3.47	0.58	-0.56	0.46	0.00	0.22
36 USA	5.98	0.53	-0.43	0.33	-0.19	0.35
37 OCD	2.81	0.99	-0.22	0.44	-0.07	0.09
38 SSA	2.65	1.08	-0.21	0.82	0.04	0.25
39 ROW	2.61	3.70	-0.61	1.42	-0.35	2.51

Total Northeast Asia trade with Europe

China		Japan		South Korea	
exports	imports	exports	imports	exports	imports
11.86	11.56	12.82	17.36	7.01	13.78

Source: Own estimations.

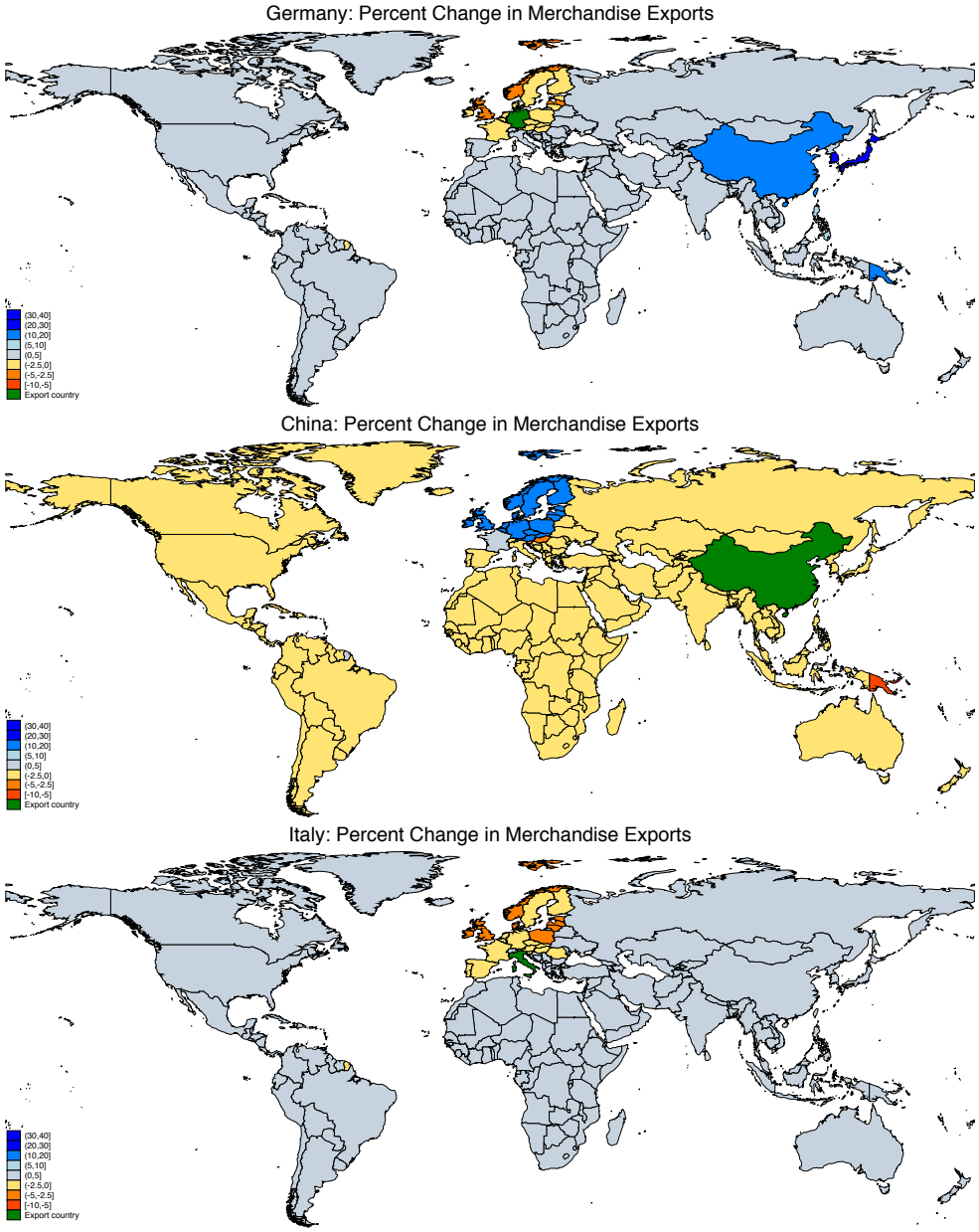
Figure 3: Trade flows after opening the NSR: percentage changes in exports by regions



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

This trade diversion pattern is further illustrated in Figure 4. First, German exports increase by more than 20% to Japan, South Korea and China, while exports to other European countries slightly decrease (by less than 5%). This pattern of changes in German exports is also replicated by the other Northwestern European countries (e.g. Austria, Belgium, Denmark, Finland, France, Ireland, Luxembourg, the Netherlands, Sweden and the United Kingdom). The second map in Figure 4 shows how Chinese exports increase significantly to Northwestern Europe while experiencing a slight decrease for the rest of the World (ROW) – a pattern that is similar to that of Japanese and South Korean exports. Finally, the third map shows how Italian exports to Northwest Europe decrease due to more competition from Asian exports (this pattern also applies to other Central and Southern European countries like Spain, Greece and Hungary). Therefore, we find that the use of the NSR shipping lanes will create strong trade diversion patterns between Europe and East Asia. This pattern of trade diversion is also shown in Table 9 in the Appendix where we have separated intra-EU trade between its three geographical sub-regions, Northeast Asia and other regions.

Figure 4: Merchandise export volume changes by country of origin



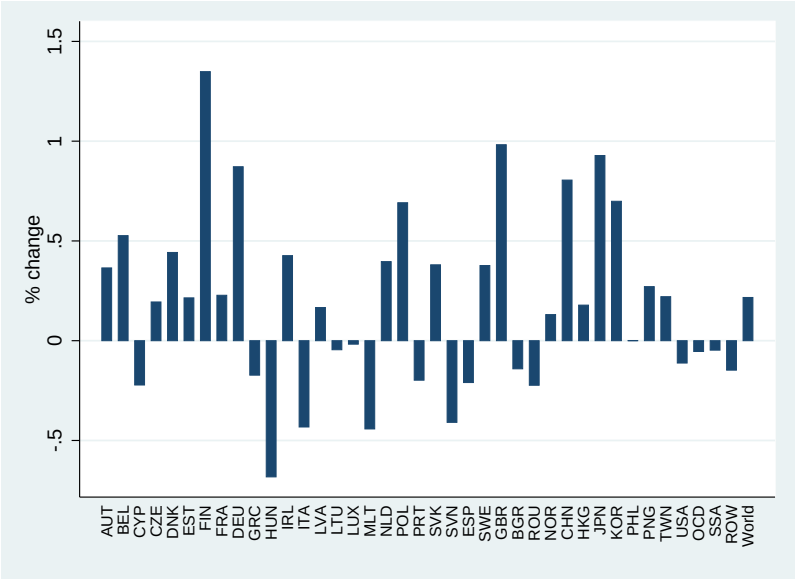
Notes: The coloured scale has different ranges. Source: Own estimations.

This pattern of trade diversion can also be seen when we look at exports at the sectoral level. For instance, Tables 10 in the Appendix shows the sectoral changes in exports to China and Germany. We observe that sectoral exports are evenly spread among all manufacturing sectors with few exceptions (e.g. S10 Forestry, S18 Other transport equipment and the service sectors). Looking at the trade flows to

Europe, in Table 11 we show the percentage changes in export sales to Germany –which has a very similar pattern from exports to other Northwestern European countries. Here we find that China, Japan, South Korea and Taiwan (not shown) increase significantly 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 5 we show the changes in aggregate export volumes by country. We observe that Northwestern 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 5: Changes in export values by countries, percentage changes



Source: Own estimations.

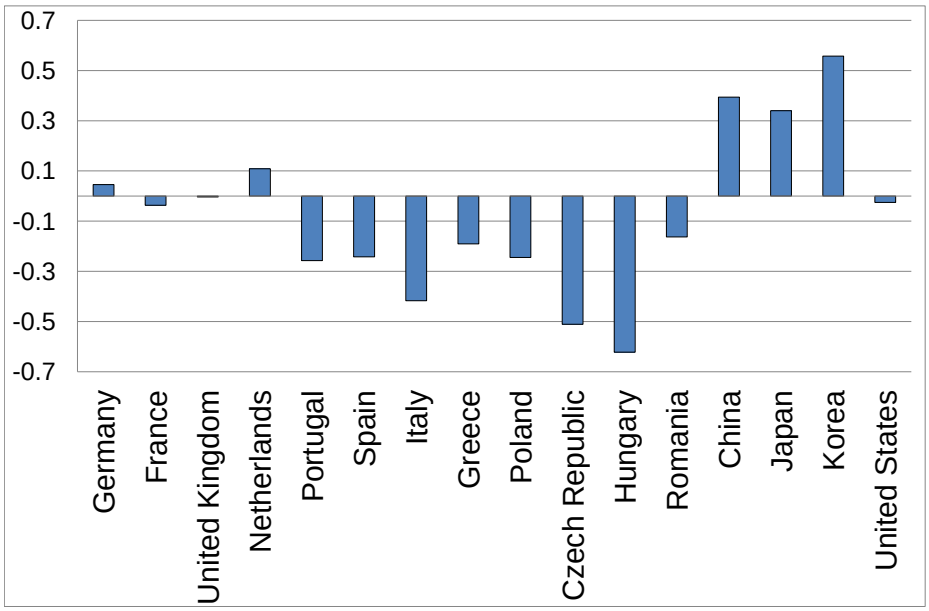
Given the relatively small aggregate trade changes, sectoral output follows a similar pattern. From Figures 8 and 9 in the Appendix we observe that most of the sectoral output in most EU countries does not change significantly. The only exception is a reduction in output for the sector other manufactures (S14), while clothing (S05) wood products (S20) also have a decrease for must countries.

5.2 Macroeconomic and labour effects

These changes in trade flows are translated into macroeconomic impacts as well. First, GDP is estimated to increase modestly in the countries that benefit directly from the NSR (see Figure 6). Northeast Asia experiences the biggest gains, while Northwestern 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. 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.[19]

Figure 6: GDP changes associated with the opening of the NSR, percentage changes



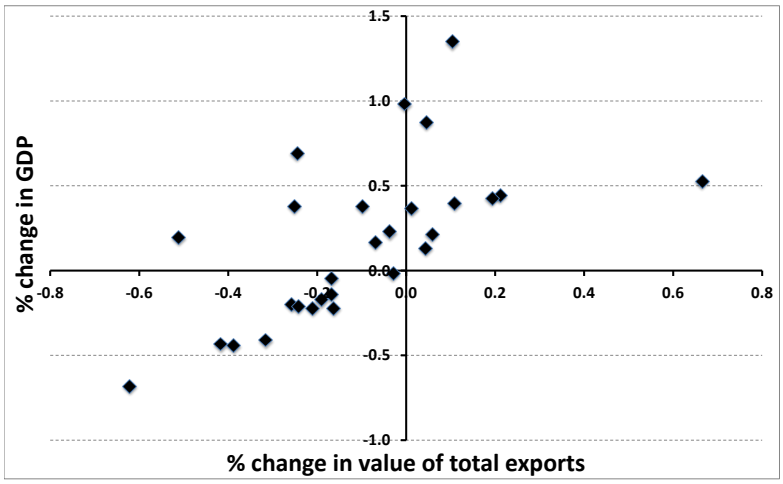
Source: Own estimations.

Likewise, in Table 12 in the Appendix we observe that GDP and welfare changes by country are related to the bilateral trade patterns. With Northwest European and Northeast Asian countries benefiting the most, while South and Eastern EU members have negative changes. Welfare changes (when measured as the equivalent variation in US$ million) follow the same pattern and the amounts are directly related to country size. There is, accordingly, a direct relationship between changes in trade values and GDP changes. This can be observed from Figure 7.

However, we do not find any sizable effects on labour market outcomes. To analyse changes in the labour market we use two different model closures. In the

[19]See for example Francois (2000), Francois *et al.* (2005), and Francois, Manchin, Norberg, Pindyuk and Tomberger (2013)).

Figure 7: Total export values and GDP percentage changes



Source: Own estimations.

first (used to estimate the information presented above) we assume sticky wages and the labour market is cleared by changes in overall employment levels.[20] In the second closure, we assume that the labour market is cleared by changes in wages. In Table 13 in the Appendix we present the changes in real wages and employment for both model closures. We observe relatively small changes in both, which are directly related to the relatively minor changes in sectoral output. We also obtain the percentage labour force displaced, which is calculated as the square root of the weight average standard deviation in sectoral employment. Moreover, the expected gradual opening of the NSR also means that there will be no large short-term labour adjustment shocks.

5.3 Changes in CO2 emissions

Regarding C02 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 Northeastern Asia. Therefore, both effects almost offset each other, but we estimate that there is nonetheless a slight increase in global emissions of 30.7 million MT CO2 (see last columns in Table 12 in the Appendix). This increase is comparable to the annual emissions for a small country (e.g. Cyprus or Latvia).[21]

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

[21] It is important to note that these particular CO2 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.

6 Summary

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References

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

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

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

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

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

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

Francois, J. F., Manchin, M., Norberg, H., Pindyuk, O. and Tomberger, P. (2013). "Reducing Transatlantic Barriers to Trade and Investment: An Economic Assessment", Final Project Report, Centre for Economic Policy Research (CEPR), London.

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

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

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

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

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

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

International Institute for Applied Systems Analysis (IIASA) (2012). "Supplementary Note for the SSP data sets", Database and Documentation SSP2.

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

Kinnard, C., Zdanowicz, C. M., Fisher, D. A., Isaksson, E., de Vernal, A. and Thompson, L. G. (2011). "Reconstructed changes in Arctic sea ice over the past 1450 years", *Nature* 479: 509–513.

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

Liu, M. and Kronbak, J. (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 Zignago, S. (2011). "Notes on CEPIIs Distances Measures: The GeoDist Database", Document de Travail No. 2011-25, CEPII.

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

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., Carter, T., Ebi, K., Edmonds, J., Hallegatte, S., E.Kemp-Benedict, E.Kriegler, Mearns, L., Moss, R., Riahi, K., van Ruijven, B. and van Vuuren, D. (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.

Rodrigues, J. (2008). "The rapid decline of the sea ice in the Russian Arctic", *Cold Regions Science and Technology* 54: 124–142.

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

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

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

Schøyen, H. and Bråthen, S. (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.

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

A Appendix

Table 5: 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 6: 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 7: Bilateral shipping distances for selected countries: current SSR and new NSR distances

From:	To:	SSR km	NSR km	% change	From:	To:	SSR km	NSR km	% change
BEL	CHN	19,996	15,778	-21%	CHN	BEL	19,914	15,477	-22%
BEL	JPN	20,976	13,841	-34%	JPN	BEL	20,894	13,759	-34%
BEL	KOR	20,458	15,091	-26%	KOR	BEL	20,378	14,792	-27%
BEL	TWN	18,801	16,491	-12%	TWN	BEL	18,722	16,190	-14%
DEU	CHN	20,556	16,263	-21%	CHN	DEU	20,478	15,942	-22%
DEU	JPN	21,536	14,302	-34%	JPN	DEU	21,458	14,224	-34%
DEU	KOR	21,019	15,575	-26%	KOR	DEU	20,941	15,257	-27%
DEU	TWN	19,362	16,976	-12%	TWN	DEU	19,286	16,655	-14%
GBR	CHN	19,799	15,521	-22%	CHN	GBR	19,723	15,217	-23%
GBR	JPN	20,779	13,576	-35%	JPN	GBR	20,703	13,499	-35%
GBR	KOR	20,262	14,834	-27%	KOR	GBR	20,186	14,532	-28%
GBR	TWN	18,605	16,234	-13%	TWN	GBR	18,531	15,930	-14%
NLD	CHN	20,017	15,738	-21%	CHN	NLD	19,942	15,436	-23%
NLD	JPN	20,996	13,793	-34%	JPN	NLD	20,922	13,718	-34%
NLD	KOR	20,479	15,051	-27%	KOR	NLD	20,405	14,751	-28%
NLD	TWN	18,822	16,451	-13%	TWN	NLD	18,750	16,150	-14%

Source: Own estimations based on data from AtoBviaC and Lasserre and Pelletier (2011).

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

	China		Japan		South Korea	
	exports	imports	exports	imports	exports	imports
1 AUT	15.45	19.12	23.13	35.99	17.35	23.05
2 BEL	12.49	21.53	22.14	30.47	20.30	22.65
3 CYP	-1.63	1.05	-0.81	0.32	-1.14	-0.18
4 CZE	11.14	24.21	18.87	34.18	13.62	25.34
5 DNK	14.27	18.30	22.40	31.19	17.25	22.66
6 EST	13.60	22.96	18.95	71.37	16.10	33.64
7 FIN	10.33	20.36	18.79	36.06	12.62	22.88
8 FRA	1.81	6.06	13.67	21.91	6.99	10.78
9 DEU	11.17	17.38	20.07	31.71	11.14	22.92
10 GRC	-1.64	0.21	-0.32	0.01	0.04	1.02
11 HUN	-2.93	2.19	-2.41	1.49	-2.35	1.66
12 IRL	12.57	21.34	24.69	32.92	21.45	34.59
13 ITA	-2.06	1.01	-1.58	0.47	-1.64	0.64
14 LVA	16.01	40.68	19.33	97.37	15.85	54.30
15 LTU	14.14	51.56	17.91	66.58	15.93	66.13
16 LUX	14.98	18.63	20.19	32.53	18.60	25.35
17 MLT	-1.84	2.03	-0.80	0.74	-0.27	1.58
18 NLD	10.90	18.72	19.04	30.65	17.41	22.81
19 POL	13.69	35.39	19.64	34.37	12.44	24.89
20 PRT	-1.00	2.55	10.00	16.10	4.46	8.96
21 SVK	10.06	18.52	18.53	33.01	13.24	26.51
22 SVN	-2.60	1.46	-1.33	0.56	-1.37	0.27
23 ESP	-1.09	1.69	10.16	13.13	4.66	6.87
24 SWE	14.19	18.03	22.28	31.62	12.74	22.13
25 GBR	14.02	19.61	22.91	31.51	10.11	24.37
26 BGR	-1.63	0.64	-1.59	0.61	-1.38	0.57
27 ROU	-2.14	0.23	-1.62	1.14	-1.38	0.86
28 NOR	13.26	17.38	22.54	28.78	12.27	20.60
29 CHN	0.00	0.00	0.07	-0.28	0.51	-0.47
30 HKG	-0.51	1.57	-0.69	0.83	-0.01	-0.02
31 JPN	-0.28	0.07	0.00	0.00	0.31	-0.50
32 KOR	-0.47	0.51	-0.50	0.31	0.00	0.00
33 PHL	-0.78	0.32	-0.19	-0.44	-0.28	0.23
34 PNG	-5.09	0.28	-2.41	-0.80	-1.17	-2.07
35 TWN	-0.75	0.55	-0.65	0.43	-0.01	0.21
36 USA	-0.65	0.37	-0.44	-0.13	-0.15	-0.04
37 OCD	-0.53	0.31	-0.25	-0.22	-0.07	-0.08
38 SSA	-0.71	0.28	-0.09	-0.19	0.39	-0.22
39 ROW	-0.88	0.45	-0.72	-0.04	-0.35	0.07

Source: Own estimations.

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

	Total intra-EU,	of which:			Northeast Asia	Other regions	Total
		South EU	East EU	Northwest EU			
Austria	-1.25	-0.06	-1.59	-1.83	24.98	0.13	0.42
Belgium	-0.47	0.48	-0.94	-0.95	18.46	-0.30	0.47
Bulgaria	-0.79	-0.12	-0.86	-0.83	0.64	0.16	-0.12
Cyprus	-0.45	-0.15	-0.50	-0.50	0.24	0.06	-0.18
Czech Republic	-0.77	1.79	-0.91	-1.47	20.75	1.55	0.10
Denmark	-0.99	0.26	-1.15	-1.27	16.98	-0.48	0.31
Estonia	-1.19	-0.51	-1.26	-1.29	22.72	0.11	0.10
Finland	-1.62	0.77	-2.39	-2.06	14.81	0.76	1.21
France	-1.15	-0.31	-1.66	-1.46	6.70	0.19	-0.02
Germany	-1.24	0.00	-1.83	-1.42	16.47	0.61	0.90
Greece	-0.61	-0.34	-0.40	-0.79	0.24	0.15	-0.18
Hungary	-1.58	0.13	-1.52	-1.87	1.29	0.76	-0.81
Ireland	-1.17	0.30	-1.83	-1.37	16.00	0.72	0.28
Italy	-1.36	-0.34	-1.65	-1.44	0.73	0.31	-0.46
Latvia	-1.18	-0.08	-0.97	-1.43	25.94	0.42	0.11
Lithuania	-1.40	-0.72	-1.22	-1.46	33.56	-0.95	-0.65
Luxembourg	-0.55	0.22	-1.00	-0.58	7.79	0.06	0.00
Malta	-1.85	-0.22	-1.42	-1.85	1.70	0.32	-0.40
Netherlands	-0.56	0.32	-1.08	-0.45	14.05	0.12	0.35
Poland	-1.24	1.25	-1.00	-1.34	32.64	-0.49	0.59
Portugal	-1.00	-0.28	-1.93	-1.24	2.22	0.12	-0.35
Romania	-0.93	-0.05	-0.44	-1.05	0.32	0.38	-0.18
Slovakia	-0.62	1.78	-0.67	-0.68	18.40	1.58	0.34
Slovenia	-1.24	-0.30	-1.33	-1.28	0.68	0.43	-0.46
Spain	-0.90	-0.34	-1.71	-0.88	2.14	0.21	-0.23
Sweden	-1.01	-0.04	-1.52	-0.99	15.63	0.04	0.40
United Kingdom	-0.35	0.41	-0.92	-0.39	14.37	0.58	0.95
China	11.80	3.50	11.75	12.74	3.23	3.71	5.18
Japan	12.78	2.50	10.53	5.87	-0.12	-0.41	1.22
South Korea	7.20	0.82	8.72	2.56	0.48	-0.23	0.87
Taiwan	0.58	-1.34	-0.51	0.48	0.52	-0.12	0.27
Hong Kong	-0.32	-0.20	-0.72	0.33	0.82	0.08	0.26
USA	-1.23	-0.22	-1.48	-0.15	0.49	0.15	0.08

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.

Table 10: Sectoral changes in export sales to China for selected countries, percentage changes

Sector	1 AUT	2 BEL	4 CZE	8 FRA	9 DEU	11 HUN	13 ITA	18 NLD	23 ESP	24 SWE	25 GBR	31 JPN	32 KOR
1 S01	21.6	21.4	21.3	7.0	21.9	1.6	1.5	21.6	2.3	22.2	23.0	1.5	0.9
2 S02	21.4	23.8	22.6	7.1	20.8	2.2	1.4	22.9	2.5	22.7	21.9	0.4	0.5
3 S03	14.0	16.6	14.6	4.7	15.5	0.9	0.8	16.2	1.6	14.5	14.6	0.8	1.2
4 S04	19.5	28.5	30.0	7.0	21.9	2.3	2.1	25.1	4.0	19.7	20.4	1.0	1.7
5 S05	19.9	23.0	20.3	6.3	19.8	2.1	1.6	19.8	2.5	20.0	18.9	0.4	0.7
6 S06	16.4	16.9	15.6	4.6	16.7	0.2	0.1	16.9	0.8	16.6	17.9	0.0	-1.1
7 S07	2.4	30.9	2.0	12.1	29.7	2.8	2.7	22.9	3.5	1.5	27.5	2.5	1.7
8 S08	19.9	21.6	19.3	7.1	22.0	1.8	1.5	20.6	2.5	20.8	23.4	1.4	1.3
9 S09	18.8	19.4	20.1	6.9	19.0	3.9	2.8	22.0	3.5	20.1	20.0	1.5	1.5
10 S10	19.6	7.7	0.9	5.1	8.4	0.8	0.4	12.8	2.7	19.4	26.2	2.2	0.8
11 S11	17.9	18.3	18.6	5.2	17.2	0.3	0.5	17.3	1.1	16.8	19.8	0.0	0.6
12 S12	51.9	40.8	45.5	11.0	28.3	6.3	4.5	39.0	7.5	32.3	35.6	-0.5	0.6
13 S13	18.5	19.8	20.8	6.7	19.0	2.8	1.9	19.9	2.9	18.8	20.4	-0.6	0.2
14 S14	32.7	17.3	40.1	11.8	37.0	4.9	3.0	39.7	5.0	33.4	31.3	1.2	2.0
15 S15	25.0	19.6	26.7	5.4	19.1	0.4	0.3	19.6	1.1	21.5	13.8	0.2	0.2
16 S16	26.1	24.8	14.5	14.4	16.9	-0.4	0.1	9.8	1.9	22.9	19.7	0.1	-0.1
17 S17	23.5	55.5	24.9	19.1	24.2	4.0	3.1	26.2	4.1	25.2	25.8	1.0	1.2
18 S18	7.5	4.7	7.5	5.6	8.3	-1.2	-0.6	6.9	-0.5	7.3	6.7	0.6	0.9
19 S19	25.3	26.6	33.5	8.8	27.1	3.0	2.5	27.0	3.6	30.5	28.1	0.7	1.2
20 S20	63.8	56.3	58.6	20.5	49.8	9.9	7.8	62.1	9.1	69.8	52.3	4.9	3.6
21 S21	0.6	0.4	0.8	0.4	0.6	0.6	0.3	0.5	0.5	0.7	0.6	-0.1	0.2
22 S22	1.2	1.8	1.4	0.6	1.2	0.4	0.3	1.2	0.6	1.1	1.0	-0.1	0.4
23 S23	1.6	-1.1	2.5	1.9	1.8	2.7	2.7	1.5	2.5	2.1	2.4	0.5	0.5
Simple average	20.4	21.5	20.1	7.8	19.4	2.3	1.8	20.5	2.8	20.0	20.5	0.9	0.9

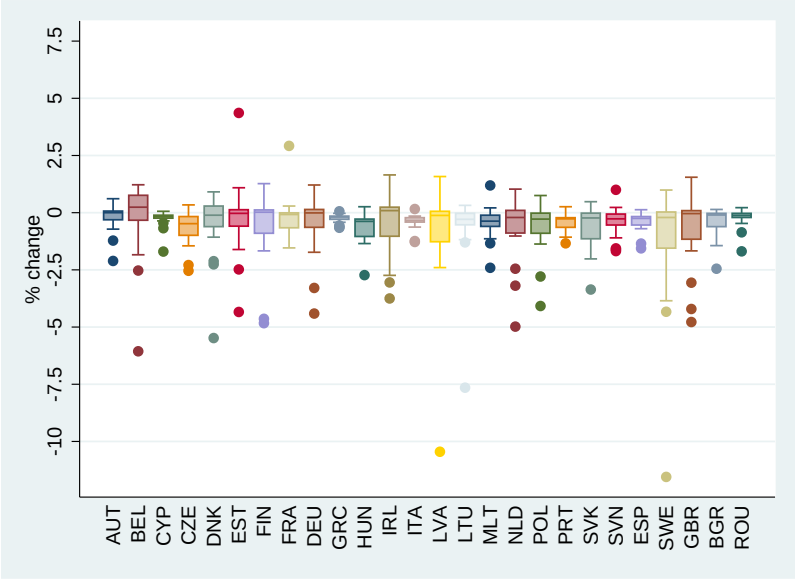
Source: Own estimations.

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

Sector	1 AUT	2 BEL	4 CZE	8 FRA	11 HUN	13 ITA	18 NLD	23 ESP	24 SWE	25 GBR	29 CHN	31 JPN	32 KOR
1 S01	0.3	-0.5	0.0	0.5	0.8	0.7	-0.5	0.6	0.4	0.1	18.2	37.7	24.8
2 S02	-0.2	1.1	0.1	-1.2	-0.8	-1.6	0.0	-1.3	0.3	-0.8	17.3	27.8	23.5
3 S03	0.2	1.4	0.4	-0.1	-0.3	-0.3	0.5	-0.1	0.4	0.4	10.7	22.9	16.6
4 S04	-1.2	-0.8	-0.1	-1.7	-1.5	-1.6	-1.0	-1.6	-1.0	-0.8	17.5	22.5	15.5
5 S05	-3.5	-1.9	-3.3	-5.3	-5.0	-5.4	-4.1	-5.3	-3.3	-5.0	10.4	19.9	13.3
6 S06	0.2	0.2	-0.5	0.4	0.7	0.6	0.1	0.5	0.2	0.4	15.4	30.6	20.4
7 S07	-0.1	-0.3	-0.4	-0.7	0.3	0.3	0.0	-0.2	-1.0	-0.6	22.8	41.0	32.2
8 S08	0.1	0.6	0.3	-0.1	0.1	-0.2	0.2	-0.1	0.4	0.3	15.5	30.0	21.1
9 S09	-2.1	-1.9	-1.2	-3.9	-2.8	-3.8	-0.2	-3.7	-0.9	-1.7	8.9	17.6	11.5
10 S10	4.0	-3.8	5.3	4.2	5.1	4.6	2.5	6.2	4.5	7.2	15.6	44.1	35.4
11 S11	0.1	0.4	1.3	0.9	1.4	1.6	-0.5	1.3	-0.1	0.9	19.3	31.7	23.9
12 S12	-10.3	-7.3	-4.2	-11.4	-11.1	-12.6	-4.3	-11.1	-4.6	-5.4	5.9	14.3	2.6
13 S13	-2.2	-1.8	-0.8	-3.0	-2.3	-3.2	-1.9	-2.9	-2.1	-1.6	11.7	18.5	14.2
14 S14	-6.0	-10.6	-4.0	-9.9	-9.4	-11.1	-2.9	-10.8	-7.1	-4.5	8.6	6.3	3.8
15 S15	-0.2	0.3	-0.2	-0.4	-0.3	-0.4	0.0	-0.4	-0.5	0.0	17.1	29.5	32.4
16 S16	-11.2	-2.3	-1.0	-1.7	-1.2	-0.8	-0.4	-1.5	-0.9	-0.4	41.1	68.2	72.6
17 S17	-4.1	-3.1	-3.1	-5.0	-4.5	-5.4	-2.7	-5.3	-2.5	-2.9	11.3	21.0	15.4
18 S18	-1.1	-3.3	-1.4	1.8	-3.4	-2.7	-1.6	-2.8	-1.3	-1.6	3.8	8.3	5.7
19 S19	-0.6	-0.3	0.4	-1.3	-0.6	-1.1	-0.2	-1.0	-0.3	0.2	22.6	34.3	26.4
20 S20	-6.4	-2.6	-2.5	-6.8	-5.2	-7.1	0.2	-7.8	-3.4	5.7	37.8	28.0	29.3
21 S21	0.2	0.0	0.4	0.0	0.2	-0.1	0.1	0.1	0.3	0.1	-0.2	-0.5	-0.2
22 S22	0.3	1.0	0.5	-0.2	-0.5	-0.5	0.3	-0.2	0.3	0.2	-0.6	-0.9	-0.5
23 S23	0.0	-2.7	0.9	0.3	1.1	1.1	-0.1	0.9	0.5	0.8	-1.2	-1.0	-1.0
Simple average	-1.9	-1.7	-0.6	-1.9	-1.7	-2.1	-0.7	-2.0	-0.9	-0.4	14.3	24.0	19.1

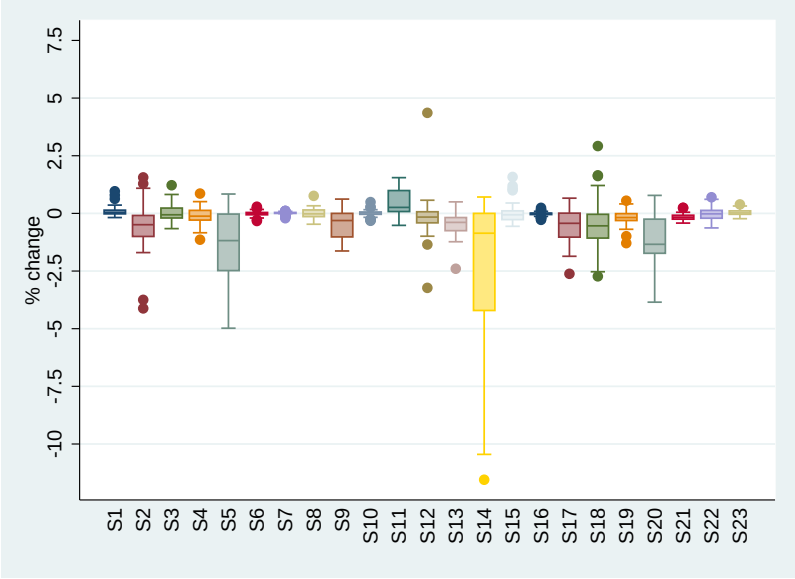
Source: Own estimations.

Figure 8: Sectoral output by EU countries, percentage changes



Source: Own estimations.

Figure 9: Output by sector for all EU countries, percentage changes



Source: Own estimations.

Table 12: CGE results on GDP, welfare and CO2 emissions

	GDP index	Welfare (per capita utility) % changes	Welfare (equivalent variation in US$ million)	CO2 emission changes (MT)	CO2 emission % changes
Austria	0.01	0.09	480	0.10	0.12
Belgium	0.67	0.81	4,996	0.34	0.25
Cyprus	-0.21	-0.21	-63	-0.04	-0.26
Czech Republic	-0.51	-0.43	-1,228	-0.58	-0.40
Denmark	0.21	0.31	1,504	0.12	0.12
Estonia	0.06	0.18	70	-0.04	-0.18
Finland	0.10	0.21	617	-0.05	-0.07
France	-0.04	-0.05	-1,840	-0.43	-0.08
Germany	0.05	0.16	6,292	-0.58	-0.08
Greece	-0.19	-0.20	-816	-0.26	-0.22
Hungary	-0.62	-0.65	-1,160	-0.20	-0.36
Ireland	0.19	0.29	1,276	0.05	0.08
Italy	-0.42	-0.42	-10,024	-1.39	-0.31
Latvia	-0.07	-0.01	-7	-0.03	-0.15
Lithuania	-0.17	-0.09	-58	-0.08	-0.42
Luxembourg	-0.03	0.01	8	-0.03	-0.14
Malta	-0.39	-0.28	-33	0.00	-0.10
Netherlands	0.11	0.21	2,424	0.06	0.03
Poland	-0.24	-0.16	-1,371	-3.03	-0.83
Portugal	-0.26	-0.26	-744	-0.12	-0.15
Slovakia	-0.25	-0.19	-286	-0.15	-0.28
Slovenia	-0.32	-0.32	-219	-0.03	-0.16
Spain	-0.24	-0.24	-4,107	-0.76	-0.19
Sweden	-0.10	-0.01	-51	-0.08	-0.10
United Kingdom	0.00	0.08	3,640	-0.39	-0.06
Bulgaria	-0.17	-0.19	-162	-0.06	-0.08
Romania	-0.16	-0.17	-486	-0.14	-0.12
Norway	0.04	0.19	1,839	-0.18	-0.19
China	0.39	0.40	60,201	58.82	0.21
Hong Kong	0.15	0.10	419	1.79	0.96
Japan	0.34	0.33	13,775	1.98	0.17
South Korea	0.56	0.53	9,350	1.99	0.24
Philippines	-0.05	-0.05	-160	-0.12	-0.07
Other Asia Pacific	0.43	0.56	1,014	0.21	0.44
Taiwan	0.09	0.08	672	0.13	0.02
United States	-0.03	-0.03	-7,316	-6.28	-0.08
Other OECD	0.01	0.03	1,932	-0.34	-0.02
Sub-Sahara Africa excl. ZAF	0.00	0.03	919	-0.16	-0.03
Rest of the World	-0.09	-0.07	-24,092	-17.90	-0.10
Total (World)	0.03			32.14	0.05

Source: Own estimations.

Table 13: CGE results for the labour market, percentage changes

	Changes in real wages				Changes in employment				labour displacement measure			
	flexible wages		sticky wages		flexible wages		sticky wages		flexible wages		sticky wages	
	unskilled	skilled	unskilled	skilled	unskilled	skilled	unskilled	skilled	unskilled	skilled	unskilled	skilled
AUT	0.34	0.37	0.04	0.07	0	0	0.01	0.01	0.81	0.88	0.81	0.88
BEL	1.10	1.11	0.67	0.69	0	0	0.13	0.14	2.57	2.77	2.57	2.77
CYP	-0.14	-0.09	-0.19	-0.15	0	0	-0.04	-0.03	0.35	0.39	0.35	0.39
CZE	0.19	0.32	-0.45	-0.33	0	0	-0.09	-0.07	1.08	1.18	1.08	1.18
DNK	0.41	0.47	0.23	0.28	0	0	0.05	0.06	1.77	1.91	1.77	1.91
EST	0.37	0.54	0.05	0.18	0	0	0.01	0.04	2.95	3.20	2.95	3.20
FIN	0.49	0.56	0.12	0.17	0	0	0.02	0.03	1.89	2.05	1.89	2.05
FRA	0.11	0.11	-0.05	-0.04	0	0	-0.01	-0.01	0.83	0.90	0.83	0.90
DEU	0.38	0.41	0.05	0.09	0	0	0.01	0.02	1.43	1.54	1.43	1.55
GRC	-0.12	-0.08	-0.17	-0.15	0	0	-0.03	-0.03	0.18	0.20	0.18	0.20
HUN	-0.38	-0.26	-0.58	-0.46	0	0	-0.12	-0.09	0.58	0.64	0.58	0.64
IRL	0.79	0.80	0.25	0.26	0	0	0.05	0.05	2.00	2.16	2.00	2.16
ITA	-0.24	-0.22	-0.37	-0.36	0	0	-0.07	-0.07	0.35	0.38	0.35	0.38
LVA	0.16	0.29	-0.09	0.01	0	0	-0.02	0.00	2.41	2.61	2.41	2.61
LTU	0.09	0.26	-0.18	-0.03	0	0	-0.04	-0.01	2.85	3.08	2.85	3.07
LUX	2.58	2.47	0.05	0.06	0	0	0.01	0.01	2.60	2.77	2.60	2.78
MLT	0.20	0.29	-0.19	-0.13	0	0	-0.04	-0.03	0.63	0.69	0.63	0.69
NLD	0.48	0.51	0.18	0.21	0	0	0.04	0.04	1.86	2.02	1.86	2.02
POL	0.15	0.30	-0.30	-0.16	0	0	-0.06	-0.03	1.25	1.36	1.25	1.36
PRT	-0.08	-0.03	-0.25	-0.20	0	0	-0.05	-0.04	0.41	0.45	0.41	0.45
SVK	0.34	0.49	-0.32	-0.16	0	0	-0.06	-0.03	1.46	1.59	1.46	1.59
SVN	-0.17	-0.13	-0.29	-0.26	0	0	-0.06	-0.05	0.60	0.65	0.60	0.65
ESP	-0.07	-0.05	-0.22	-0.19	0	0	-0.04	-0.04	0.38	0.41	0.38	0.41
SWE	0.29	0.35	-0.06	0.00	0	0	-0.01	0.00	3.31	3.57	3.31	3.57
GBR	0.22	0.28	0.01	0.06	0	0	0.00	0.01	1.68	1.82	1.68	1.82
BGR	-0.20	-0.09	-0.29	-0.20	0	0	-0.06	-0.04	0.56	0.62	0.56	0.62
ROU	-0.14	-0.11	-0.23	-0.21	0	0	-0.05	-0.04	0.37	0.40	0.37	0.41
NOR	0.15	0.16	0.11	0.12	0	0	0.02	0.02	2.76	2.98	2.76	2.98
CHN	0.29	0.28	0.27	0.25	0	0	0.05	0.05	0.42	0.46	0.42	0.46
HKG	-0.01	0.00	0.07	0.07	0	0	0.01	0.01	1.25	1.36	1.25	1.36
JPN	0.19	0.19	0.28	0.29	0	0	0.06	0.06	0.43	0.47	0.43	0.47
KOR	0.45	0.44	0.42	0.41	0	0	0.08	0.08	0.65	0.70	0.65	0.70
PHL	0.04	0.05	-0.06	-0.06	0	0	-0.01	-0.01	0.25	0.27	0.25	0.27
PNG	0.43	0.43	0.47	0.47	0	0	0.09	0.09	0.48	0.52	0.48	0.52
TWN	0.12	0.11	0.06	0.05	0	0	0.01	0.01	0.35	0.38	0.35	0.38
USA	-0.02	-0.02	-0.04	-0.04	0	0	-0.01	-0.01	0.29	0.32	0.29	0.32
OCD	-0.03	-0.02	-0.01	0.00	0	0	0.00	0.00	0.20	0.22	0.20	0.22
SSA	-0.03	-0.02	-0.01	-0.02	0	0	0.00	0.00	0.26	0.28	0.26	0.28
ROW	-0.10	-0.08	-0.11	-0.09	0	0	-0.02	-0.02	0.19	0.21	0.19	0.21

Source: Own estimations.