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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 in a multi-sector Eaton and Kortum model with intermediate linkages. 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 and welfare effects for the countries involved. 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, 2012;

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Vavrus et al., 2012).[1] Recent satellite observations, furthermore, suggest that the climate model simulations may be underestimating the melting rate (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 Northwestern 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

[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).

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 studies (Shepherd *et al.*, 2012; Kerr, 2012; Stroeve et al., 2012; Slezak, 2013) has broadened the consensus in favour 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; Rogers et al., 2015).[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 an increased 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. In the second step we map out a multi-sector general equilibrium model with intermediate linkages and trade modelled as in Eaton and Kortum (2002) and derive a gravity equation to structurally estimate the trade elasticities and to map the new distance calculations –for both the SSR and the NSR– into estimations

[2]These include recent shipping milestones: the fastest crossing Barents Observer (2011b) and the first supertanker to use the NSR Barents Observer (2011a).

[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. For instance, we ran simulations using 2020 and 2050 as our benchmark year, and our main results remain robust to these changes.

of the bilateral trade cost reductions between trading partners at the industry level. In the third step we simulate the effect of the commercial opening of the NSR on bilateral trade flows, macroeconomic outcomes, labour effects and changes in CO2 emissions employing our theoretical model.

With our model setup and calibration we are in the middle between the older computable general equilibrium (CGE) models (cf. Dixon and Jorgenson, 2013), and the recent quantitative trade models (see Costinot and Rodríguez-Clare, 2013, for an overview). The interaction of both analytical frameworks generates important synergies. For instance, following the new quantitative trade models we improve the CGE estimations in two fundamental ways. First, we model trade linkages with the improved micro-founded Eaton and Kortum (2002) structure. Second, we structurally estimate the trade parameters employing a gravity model derived from the theoretical model using the same trade data that is used in numerical simulations. On the other hand, we retain important elements of CGE modelling that are not present in the new quantitative trade models. First, we work with a detailed and consistent dataset for multi-sectors and countries with trade costs that explicitly include export taxes, international transport costs and import tariffs varying by country-pairs and sectors. Such a detailed break-down of overall trade costs is not present in recent quantitative trade models.[5] Second, we use a richer general equilibrium framework that includes non-homothetic preferences, accounts for government expenditures, overall savings and investment, multiple factors of production with varying degrees of mobility, and linkages to emissions data. Thus, our model is a large multi-sector implementation of an Eaton-Kortum model embedded in a CGE framework, where we use econometric estimations of the Eaton-Kortum derived gravity equation to parameterise the key trade and demand equations in the CGE model.

The NSR reduces shipping distances and time between Northwestern Europe and Northeast Asia by about one third. These overall trade cost reductions can further be separated between actual shipping cost reductions (i.e. fuel savings and other transport costs) and distance-related iceberg trade costs (e.g. transport time savings that can effectively create new supply chains in certain industries). We find average transport cost reductions of between 20% and 30% between both regions using intensively the NSR, while iceberg trade cost reductions are estimated to be around 3% of the value of goods sold.

Using our model, we find that the direct consequence of opening-up the NSR is that international shipping (volume by distance) is reduced by 0.43%, but global trade volumes increase by 0.21%. Although global trade volume changes are not radically high, they are completely concentrated in trade increases that average around 10% between Northeast Asia (i.e. China, Japan and South Korea) and Northwestern Europe. We estimate that the share of World trade that is re-routed through the

[5] Caliendo and Parro (2015) employ a quantitative Eaton-Kortum trade model to evaluate the effect of NAFTA, arguing against the use of CGE-models claiming that they are too much a black box. By clearly mapping out the structure of our model, we do not consider our model specification to be a black box. Furthermore, the detailed break-down of trade costs is essential for our analysis of the NSR.

NSR will be of 5.5%. For instance, 15% 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.[6] 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 Northeast Asia and Northwestern 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 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 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. Northeast Asia and Northwestern Europe experiences the biggest gains. 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 negotiations.[7] Moreover, there are small labour market effects at the aggregate and sectoral level, so there is relatively little labour displacement effects, which will not represent an important shock.

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.

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

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

[7] See for exampleFrancois (2000), Francois et al. (2005), and Francois et al. (2013).

estimate the new water-transportation distances in Section 3. In the next section we map out the theoretical structure to evaluate the impact of the NSR. In section 5 we discuss calibration of the model, derive a gravity equation and estimate the gravity equation to calculate the effect of the new distance measures on trade costs. The simulations and macroeconomic results are presented in Section 6. Section 7 concludes by summarising our main results.

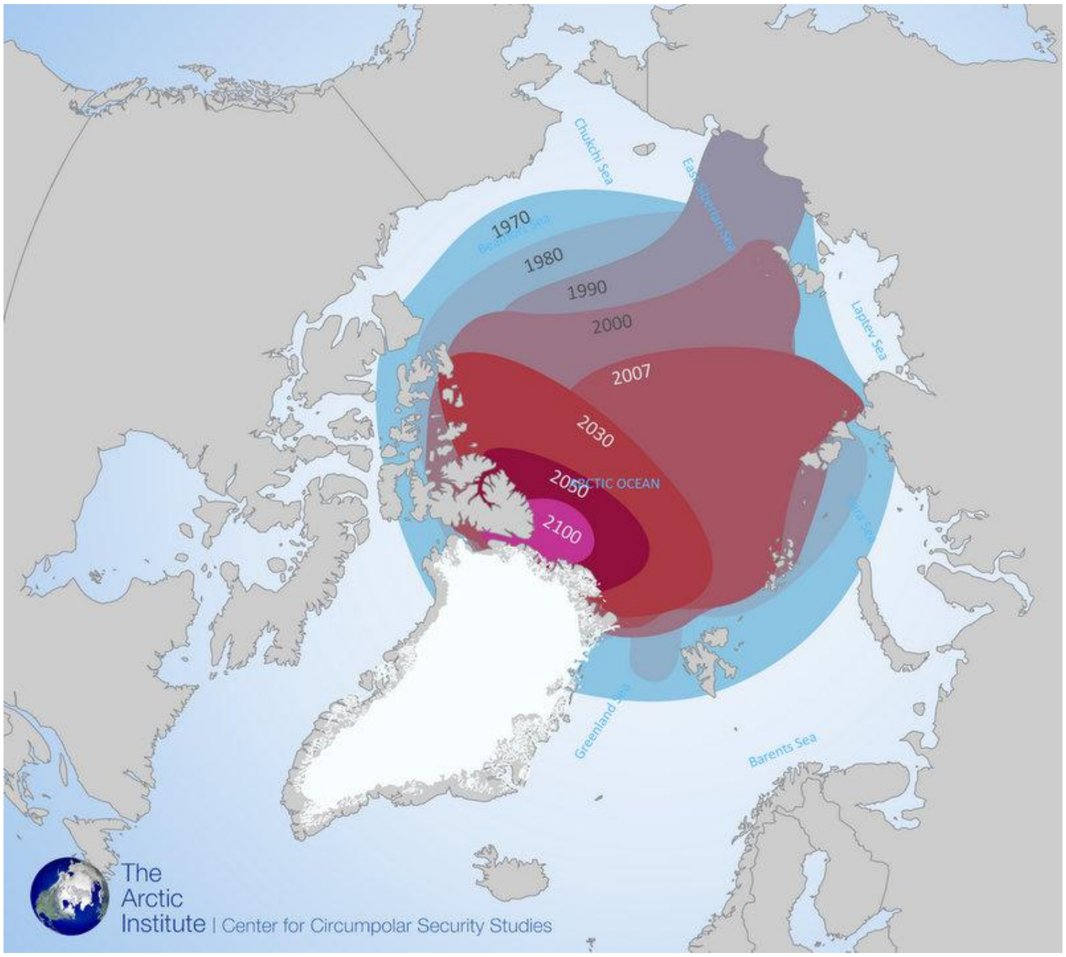
2 Commercial feasibility of the Northern Sea Route

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. As mentioned before, there is ample scientific evidence of the melting of the Arctic ice cap (Rodrigues, 2008; Kinnard et al., 2011; Comiso, 2012), that it will continue melting in the future (Wang and Overland, 2009, 2012; Vavrus et al., 2012), and other studies even suggest that the melting process may accelerate in the future as well (Kattsov et al., 2010; Rampal et al., 2011). Stammerjohn et al. (2012) note that already some Arctic regions are ice free now more than predicted by climate models for 2030, while in a meta-analysis of model results Rogers et al. (2015) identify a median prediction of 2034 for an ice free Arctic in September. These 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. These predictions have been also supported by more recent research (Wang and Overland, 2012).

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 stakeholders to develop the NSR, it is expected that these logistic limitations will be gradually overcome in the near future.[8]

[8]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

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 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 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)

throughout the route. In addition, Russia has also already started setting up 10 relief ports along the route.

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. 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 (2020) or later one (2050).[9]

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.[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 Northeast 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

[9] As a robustness analysis, we use these two different years as our benchmarks: 2020 and 2050. Our results show that 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 to the use of different years. The results fro 2020 and 2050 are available upon request.

[10] 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. 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% of world trade in volume and 80% in value –and the overwhelming majority of trade between non-neighbouring countries– is carried by ship (OECD, 2011, 2013).[12] For the country pairs and trade flows we focus on here, water transportation, or multi-modal transport (water and land) accounts for a majority of 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.[13] 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 [14] we assume that a port in a neighbouring country is used,

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]The rest moves primarily by land. 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).

[13]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.

[14]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,

so 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 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).[15] 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.[16] 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 37% from Japan to North European countries, while the same figure is around 31% for South Korea, 23% for China and 17% for Taiwan.

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

[15]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.

[16]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).

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 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 Model

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 are used in different countries. Therefore, we employ a general equilibrium model with multiple countries, multiple sectors with intermediate linkages, and multiple factors of production. Trade is modelled as in Eaton and Kortum (2002) with the remaining structure of the model largely following the standard GTAP CGE model (Hertel, 2013).

4.1 General structure

Due to space constraints we assume that the reader is familiar with conventional production functions like Cobb-Douglas, CES and Leontief. There are $J = 110$ countries. In each country j utility is a Cobb-Douglas function over three aggregate goods, private goods q_j^p, public goods q_j^g, and savings q_j^s. Preferences for private goods in turn are described by the non-homothetic Constant Distance Elasticity (CDE) function over 16 sectors s. With CDE preferences the model allows for shifting average and marginal budget shares as a country grows. At the same time the model stays tractable in a setting with a large number of countries and sectors, since a limited number of parameters can be calibrated from income and own-price elasticities of demand. CDE preferences can be described by the following implicit expenditure function:

$$\sum_{s=1}^{S} \alpha_{js} \left(q_j^p\right)^{\gamma_{js}\eta_{js}} \left(\frac{p_{js}^p}{x_j^p}\right)^{\gamma_{js}} = 1 \tag{1}$$

where p_{js}^p is the price of private goods in country j and sector s, x_j^p are private expenditures in country j and α_{js}, γ_{js} and η_{js} are parameters (called respectively the distribution, substitution and expansion parameters). Demand q_{js}^p follows from log-differentiating equation (1) with respect to p_{js}^p and x_j^p, and reorganising we obtain:

$$q_{js}^p = \frac{\alpha_{js} \left(q_j^p\right)^{\gamma_{js}\eta_{js}} \left(\frac{p_{js}^p}{x_j^p}\right)^{\gamma_{js}-1} \gamma_{js}}{\sum_{u=1}^{S} \alpha_{ju} \left(q_j^p\right)^{\gamma_{ju}\eta_{ju}} \left(\frac{p_{ju}^p}{x_j^p}\right)^{\gamma_{ju}} \gamma_{ju}} \tag{2}$$

Preferences for spending by the public sector across the 16 sectors are CES. Including savings in the static utility function implies that a shift away from future consumption and savings towards current consumption would have large welfare effects. The formal underpinning comes from Hanoch (1975) who showed that the expressions for consumption in an inter-temporal setting can also be derived from a static utility maximisation problem with savings in the utility function. Savings are used to finance investments. Savings in all countries are collected by a "global bank" channeling the savings to investment in different countries with an incentive to invest more in countries with a higher rate of return. Rates of return are not equalised in the model, though, to prevent large swings in investment demand.

4.2 International trade

Within each of the 16 sectors production takes place as in Eaton and Kortum (2002). So there is a continuum of varieties each country can produce under perfect competition with consumers having a CES utility function across the continuum. The cost of delivering a variety from source i to destination j in sector s is given by:

$$p_{ijs} = \frac{c_{is} t_{ijs}}{z} \tag{3}$$

where c_{is} is the price of input bundles in country i and sector s and t_{ijs} is the composite of trade costs expressed in power terms. The productivity z is drawn from a Frechet distribution with technology parameter z_{is} and dispersion parameter θ_s, as:

$$P\left(z_{is} \leq z\right) = \exp\left(-\left(\frac{z}{z_{is}}\right)^{-\theta_s}\right) \tag{4}$$

Composite trade costs t_{ijs} consist of one plus the export tax et_{ijs}, one plus the international transport margin itm_{ijs}, one plus the import tariff ta_{ijs}, and iceberg trade costs τ_{ijs}, which in turn consists of an observable component $\overline{\tau}_{ijs}$ driven by gravity type variables and an unobservable component $\widetilde{\tau}_{ijs}$, such that:

$$t_{ijs} = \left(1 + et_{ijs}\right)\left(1 + itm_{ijs}\right)\left(1 + ta_{ijs}\right)\overline{\tau}_{ijs}\widetilde{\tau}_{ijs} \tag{5}$$

Because of the detailed GTAP-data we can include also export taxes and international transport margins as components of trade costs. This is an important improvement on previous Eaton-Kortum multi-sector applications and it allows us to explicitly model international transport costs and how they are affected by the NSR.

The international transport margin itm_{ijs} is equal to payments to the value of international transport services $vits_{ijs}$ divided by the FOB value of trade v_{ijs}^{fob}. The demand for international transport services is proportional to the demand for export goods. International transport services are supplied by all countries and aggregated into global transport services by a Cobb-Douglas production function.[17]

c_{is} is the price of input bundles used for production in country i and sector s, determined by the price of intermediates used from all sectors and the price of factor input bundles. The choice between the aggregates of intermediates and factor inputs is described by a Leontief production function. Also the choice between intermediates from different sectors is Leontief. There are five different factor inputs: land, unskilled and skilled labour, capital, and natural resources. The choice between factor input bundles is CES. Land and natural resources are not perfectly mobile between sectors, and are modelled by an elasticity of transformation function.

With our setup the quantity sold from i to j at the sectoral level, q_{ijs}, is given by:

$$q_{ijs} = \frac{\left(\frac{c_{is}}{z_{is}} t_{ijs}\right)^{-\theta_s} q_{js}}{\sum_{k=1}^{J}\left(\frac{c_{ks}}{z_{ks}} t_{kjs}\right)^{-\theta_s}} \tag{6}$$

[17]Due to a lack of data there is no link between the supplying country and the demanding countries of these services.

q_{js} is the total demand for goods in sector s in country j, reflecting demand for intermediates by firms, demand for capital goods, and demand for public and private goods. A reduction in trade costs as a result of for example the NSR generates both more trade along the intensive and the extensive margin in the model. With lower trade costs there are more sales of each variety within a sector and more varieties are sold.

Eaton and Kortum (2002) only express the value of sales. We work with quantities, since our numerical model is expressed in quantities. Because the price distribution in country j of goods bought from country i is identical for all sources i (property b on page 1748 of Eaton and Kortum, 2002), the quantity share is identical to the volume share in the Eaton and Kortum model.

5 Calibration of the model

5.1 Gravity estimation of trade parameters

The trade parameters required to implement the model numerically are the dispersion parameters θ_s, the technology parameters z_{is} and the trade costs t_{ijs}. To obtain the dispersion parameters we estimate a gravity equation following from the theoretical structure with Eaton and Kortum production. The expression for the value of trade v_{ijs} is identical to the expression for the quantity of trade in equation (6), except for the fact that the total quantity demanded q_{js} is replaced by the total value demanded. Capturing $(\frac{c_{is}}{z_{is}})^{-\theta}$ by an exporter fixed effect d_{is} and the value demanded by an importer-fixed effect d_{js} and dividing by one plus the import tariff gives the following gravity equation for the value of trade v_{ijs} in CIF terms:[18]

$$\ln v_{ijs}^{cif} = d_{is} + d_{js} - (\theta_s + 1) \ln (1 + ta_{ijs}) (1 + itm_{ijs}) + \beta_s \ln x_{ijs} + \varepsilon_{ijs} \qquad (7)$$

where x_{ijs} consists of observable variables explaining iceberg trade costs τ_{ijs} (and the export tax et_{ijs}). As observable variables we include the standard gravity variables: distance, common colony, common language, common border (contiguous), former colony and dummies for shallow, medium and deep free trade agreements (FTA).[19] Preferential trade agreements are free trade agreements and customs unions that have been agreed at least four years previously (Dür et al., 2014). Besides these traditional gravity regressors, we include two political economy variables, PE index 1 and PE index 2, measuring the pairwise similarity of the two trading partners. These variables reflect evidence that homophily is important in explaining direct economic and political linkages (De Benedictis and Tajoli, 2011). The two political

[18] The value of trade in our theoretical model is inclusive of tariffs paid. So to get the value of trade in CIF terms, thus excluding the import tariff, we divide by one plus the import tariff.

[19] Following Egger et al. (2011), we instrument preferential trade agreements. As explanatory variables in the first stage regression we include the variables also present in the gravity equation (except for tariffs) as well as lagged trade network embeddedness (Easley and Kleinberg, 2010; De Benedictis and Tajoli, 2011; Zhou, 2011) and a variable for the economic mass of the two trading partners together, measured as GDP of the source country times GDP of the destination country.

economy variables are calculated as the two first principal components of the following four variables: the difference in polity, the functioning of governance difference, the corruption score difference, and the difference in civil society scores.

Following the theoretical gravity equation, tariffs and the international transport margin have the same coefficient and are thus included as one combined variable, $\ln(1+ta_{ijs})(1+itm_{ijs})$, called Trade Cost in Table 2. As tariff variable $\ln(1+ta_{ijs})$ we employ the log difference between the most favoured nation (MFN) tariff rate and the preferential tariff rate (based on FTAs), with the MFN rate also captured by the importer fixed effect. Data on the international transport margin are taken from the GTAP database. Since data on transport margins are only available for a limited number of countries, we use fitted values for the missing observations on the transport margin from a regression of transport margins on the same set of explanatory variables as those used in the gravity equation (excluding tariffs).

We estimate equation (7) using a sample of 110 countries in 2011. Trade data are taken from the GTAP database to have consistency with the CGE simulations.[20] Data for tariffs come from the World Bank/UNCTAD WITS database. Distance data, as discussed above, are based on the length of shipping routes. Other 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). Following Santos Silva and Tenreyro (2006, 2011), we estimate equation (7) with Poisson pseudo-maximum likelihood (PPML) for trade for each manufacturing sector in the computational model.[21]

The results are shown in Table 2. The tariff elasticities give us one plus the dispersion parameters θ_s. The distance elasticities will be used to calculate the total trade cost reductions as a result of the reduction in shipping distances. Since we cannot estimate tariff elasticities for the services sector, we use the trade elasticities employed in the GTAP model implying a value of 2.8 for the dispersion parameters.

To shed light on the importance of changes in shipping distance, we explore how much the variation in distance contributes to the variation in trade flows. We do this in two ways. First, we show that distance explains between 3% and 19% of the variation in trade flows in the different sectors with all control variables (see the last row of Table 2). Second, due to multicollinearity with variables like FTA, we have also evaluated the change in the pseudo-R2 at the sectoral level when including distance in a regression of trade values with only importer and exporter fixed effects (see Table 7 in the Appendix). This exercise shows that including distance makes a huge difference, raising the R2 by 18% to 53% in the different sectors. So the change in shipping distance as a result of the NSR is an important factor to explain variation in trade flows.

The conventional approach to obtain trade costs t_{ijs} and the technology parameters z_{is} in the Eaton and Kortum model starts with estimation of a gravity equation as in equation (7). Trade costs are equal to the fitted trade values based on the

[20] Using COMTRADE data gives almost exactly the same coefficient estimates.

[21] The 16 sectors are composed of 11 manufacturing sectors and 5 services sectors.

Table 2: PPML gravity estimates for manufacturing sectors

	BT	CRP	ELE	MTL	MVH	OGD	OMC	PRA	PRE	PRF	P_C
trade costs	-1.700	-5.546	-13.489	-7.945	-3.396	-5.485	-13.940	-3.724	-6.483	-3.360	-11.386
	(3.29)***	(5.48)***	(4.93)***	(6.17)***	(2.96)***	(6.08)***	(7.45)***	(3.63)***	(10.25)***	(3.77)***	(4.10)***
ln(distance)	-0.665	-0.422	-0.394	-0.491	-0.464	-0.585	-0.348	-0.712	-0.604	-0.609	-0.591
	(31.02)***	(21.68)***	(16.42)***	(26.56)***	(18.78)***	(25.27)***	(18.53)***	(32.81)***	(35.10)***	(22.54)***	(14.19)***
PE index 1	-0.237	0.004	0.239	0.047	-0.035	0.169	0.109	0.139	0.032	0.169	0.018
	(5.39)***	(0.16)	(6.13)***	(1.97)**	(0.78)	(5.74)***	(3.25)***	(4.08)***	(1.21)	(5.61)***	(0.60)
PE index 1	0.062	-0.190	-0.098	0.063	-0.073	-0.028	-0.139	0.060	-0.043	-0.092	0.103
	(1.04)	(5.68)***	(1.94)*	(1.10)	(1.49)	(0.81)	(3.78)***	(1.05)	(1.26)	(1.39)	(1.64)
common colony	0.167	-0.038	0.679	0.160	-0.546	0.309	0.034	-0.234	-0.176	0.281	0.417
	(0.85)	(0.24)	(2.11)**	(0.58)	(1.66)*	(0.87)	(0.16)	(1.35)	(0.71)	(1.00)	(1.85)*
common ethnic language	0.385	0.306	0.560	0.306	0.208	0.284	0.410	0.560	0.403	0.424	0.390
	(3.29)***	(2.73)***	(3.70)***	(2.95)***	(1.52)	(2.48)**	(4.05)***	(5.16)***	(5.11)***	(2.19)**	(2.58)***
contiguous	0.221	0.529	0.429	0.799	0.544	0.902	0.575	0.644	0.763	0.754	0.948
	(1.86)*	(6.49)***	(3.39)***	(10.44)***	(4.36)***	(9.84)***	(6.12)***	(4.50)***	(10.08)***	(3.37)***	(4.42)***
former colony	0.749	0.268	0.120	0.455	-0.364	0.275	0.293	0.130	0.122	0.917	0.178
	(4.72)***	(1.73)*	(0.70)	(3.13)***	(1.81)*	(2.34)**	(2.33)**	(1.06)	(1.27)	(3.82)***	(0.96)
shallow FTA (DESTA=1,2)	-0.921	0.576	0.348	0.335	-0.217	0.241	0.946	-0.428	0.887	-0.618	0.921
	(3.34)***	(3.61)***	(1.44)	(2.61)***	(0.60)	(1.02)	(5.04)***	(1.92)*	(3.82)***	(1.24)	(2.57)**
medium FTA (DESTA=3,4,5)	-0.193	0.070	-0.201	-0.140	0.594	-0.442	-0.415	0.088	-0.203	1.108	1.362
	(0.94)	(0.40)	(0.67)	(0.74)	(2.55)**	(3.03)***	(2.70)***	(0.49)	(1.87)*	(3.43)***	(4.14)***
deep FTA (DESTA=6,7)	1.493	1.163	1.266	0.811	2.083	1.028	1.504	2.383	1.252	1.569	4.088
	(4.00)***	(5.54)***	(4.04)***	(3.82)***	(8.11)***	(3.52)***	(5.06)***	(8.91)***	(7.21)***	(4.20)***	(10.09)***
European Union	0.527	0.632	0.710	0.175	1.008	0.343	-0.035	1.017	0.449	0.622	-1.023
	(2.93)***	(5.09)***	(3.75)***	(1.41)	(7.02)***	(3.05)***	(0.30)	(6.74)***	(3.91)***	(1.97)**	(1.60)
N	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863	9,955
pseudo R^2	0.9874	0.9766	0.9619	0.9789	0.9763	0.9849	0.9760	0.9854	0.9879	0.9369	0.8530
V: distance share of variance	0.1886	0.0401	0.0435	0.0617	0.0583	0.0757	0.0270	0.1443	0.0948	0.1095	0.0404

Notes: PPML estimates, all including source and destination fixed effects (not shown). PE index 1 and PE index 2 are composite variables of similarity in political economy indicators as discussed in text. The variables shallow FTA, medium FTA and deep FTA have been instrumented for. Standard errors in parenthesis. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Sector codes: B_T beverages & tobacco; CRP chemicals, rubber, plastics; ELE electrical machinery; MTL metals; MVH motor vehicles; OGD other goods; OMC other machinery; PRA primary agriculture; PRE primary energy; PRF processed foods; P_C petrochemicals. The statistic V, for predicted log-linear trade values, is $b_2^2 VAR(ln(distance))/VARln(trade)$.

observable variables and importer (exporter) specific trade costs. The technology parameters are obtained by writing the technology parameters z_{is} as a function of the exporter (with importer specific trade costs) or importer fixed effects (with exporter specific trade costs) and the price of input bundles c_{is}(Eaton and Kortum, 2002; Shikher, 2012; Levchenko and Zhang, 2015). With data on c_{is}, the z_{is} can then easily be obtained.

We follow a different route, inspired by recent work by Egger and Nigai (2014) and Egger and Nigai (2015) and the CGE literature. Egger and Nigai (2014) argue that exporter and importer fixed effects are picking up part of the unobservable trade costs and only importer or exporter specific unobserved trade costs is not enough to account for that. Neglecting the unobservable trade costs results in a relatively large difference between actual and predicted trade values. In calibrating an Eaton and Kortum economy, Egger and Nigai (2015) propose to calculate trade costs and technology parameters from actual import shares, imposing that there is a perfect fit between actual and predicted normalised trade shares and that income is equal to exports to all destination countries.[22] We follow this approach and thus solve t_{ijs} and T_{is} from the following set of equations:

$$\frac{\omega_{ijs}}{\omega_{jjs}} = \frac{\left(\frac{c_{is}}{z_{is}} t_{ijs}\right)^{-\theta_s}}{\left(\frac{c_{js}}{z_{js}} t_{jjs}\right)^{-\theta_s}} \tag{8}$$

$$prod_{is} = \sum_{j=1}^{J} \frac{\left(\frac{c_{is}}{z_{is}} t_{ijs}\right)^{-\theta_s}}{\sum\limits_{k=1}^{J} \left(\frac{c_{ks}}{z_{ks}} t_{kjs}\right)^{-\theta_s}} dem_{js} \tag{9}$$

where ω_{ijs} is the market share of imports from country i in total demand in country j and $prod_{is}$ and dem_{js} are respectively the value of production in country i and demand in country j. In comparison with a calibration based on observable trade costs only, the perfect fit is achieved, because total trade costs consist of a mix of observable and unobservable trade costs. Since our numerical model is written in relative changes the exact value of trade costs t_{ijs} and technology T_{is} following from equations (8)-(9) is irrelevant for model simulations. It is only required that the predicted import shares are equal to the actual market shares in the baseline.

5.2 Trade cost reductions

The reduction in distance as a result of the NSR has an impact on two types of trade costs, international transport services and iceberg trade costs. The percentage reduction in international transport services costs, $\Delta \ln its_{ijs}$, (the "atall" in the GTAP code) is calculated as the reduction in distance times the elasticity of international transport services costs with respect to distance, $\eta_{its,dist}$:

$$\Delta \ln its_{ijs} = -\eta_{its,dist} \left(\frac{\text{NSRdistance}_{ij}}{\text{distance}_{ij}} - 1 \right) \tag{10}$$

To calculate $\eta_{its,dist}$ international transport services are regressed on distance, while controlling for port infrastructure and including industry fixed effects. This equation is estimated restricting the sample to European and East Asian countries for three reasons. First, the quality of the transport service data is poor for many other countries (in particular the African countries). Second, the NSR is about a reduction in shipping distances between Europe and East Asia. And third, the empirical literature on the determinants of shipping costs shows that the effect of is non-linear (OECD, 2008). Table 3 shows that the estimated elasticity $\eta_{its,dist}$ is equal to 0.789.[23]

[22] This approach is similar to the approach in the CGE literature with the Armington shifters set such that there is a perfect fit between actual an fitted trade flows.

[23] A series of papers find that the elasticity of shipping costs to distance is around 0.2 (Radelet and Sachs, 1998; Fink et al., 2000; Limão and Venables, 2001; Micco and Pérez, 2002; Clark et al.,

Table 3: Regression of shipping costs and shipping distances for Europe-Asia trade

ports	-0.047
	(4.12)***
ln(distance)	0.789
	(5.56)***
_cons	-4.216
	(3.02)***
R^2	0.64
N	2,448

Notes: PQML estimates of shipping rate (in percent). Includes industry dummies. Ports is a WEF/World Bank index of port quality.

In Table 4 we present a summary of the transport cost reductions. These are sector-specific and vary by trading country pairs. Moreover, the transport cost changes are not symmetric –i.e. the trade costs from China to Germany are different than from Germany to China.

A fall in distance does not only affect international transport service costs but also other barriers to bilateral trade such as information costs, business networks, cultural barriers, time, coordination, and other non-shipping service costs (cf. Hummels and Schaur, 2013). In our framework, these additional trade barriers are captured by the iceberg costs, so the NSR will also reduce iceberg trade costs. The percentage reduction in iceberg trade costs $\Delta \ln \tau_{ijs}$ (the "ams" in the GTAP code) is calculated as the reduction in distance as a result of the NSR times the elasticity of trade costs with respect to distance. The elasticity of trade costs with respect to distance is calculated from the distance and tariff elasticicities in Table 2. This gives the following expression for $\Delta \ln \tau_{ijs}$:

$$\Delta \ln \tau_{ijs} = \frac{\beta_{s,\text{distance}}}{\theta_s + 1} \left(\frac{\text{NSRdistance}_{ij}}{\text{distance}_{ij}} - 1 \right) \tag{11}$$

Since international transport services are also included as a regressor in the gravity equation, the effect of distance on trade costs and thus on trade flows through international transport services is accounted for separately. Therefore, we can attribute the entire effect of distance from the gravity equation to a reduction in iceberg trade costs. Our estimates of $\Delta \ln \tau_{ijs}$ are summarised in Table 5 below. Note that these iceberg trade costs are also country-pair and sector-specific and are also not symmetric.

2004). However, OECD (2008) use the most comprehensive shipping costs dataset to date and find that the effect is non-linear, presents large variations between goods, and is asymmetric in costs between the same routes. Therefore, our relatively high elasticity can be reconciled with the existing literature, because distance seems to matter more for shipping costs between East Asia and Europe.

Table 4: International transport cost reductions for 11 non-services sectors for selected countries.

		cost reductions					cost reductions		
From:	To:	average	max	min	From:	To:	average	max	min
DEU	CHN	21.73	22.15	17.48	CHN	DEU	20.49	20.89	16.48
DEU	JPN	33.07	33.71	26.60	CHN	FRA	4.69	4.78	3.77
DEU	KOR	26.62	27.14	21.42	CHN	GBR	21.19	21.61	17.05
					CHN	NLD	20.96	21.37	16.86
FRA	CHN	6.37	6.50	5.13					
FRA	JPN	21.00	21.41	16.89	JPN	DEU	32.95	33.59	26.50
FRA	KOR	12.77	13.02	10.27	JPN	FRA	20.96	21.37	16.86
					JPN	GBR	34.00	34.67	27.35
GBR	CHN	22.41	22.84	18.02	JPN	NLD	33.65	34.31	27.07
GBR	JPN	34.13	34.80	27.45					
GBR	KOR	27.47	28.01	22.10	KOR	DEU	25.40	25.90	20.43
					KOR	FRA	11.13	11.35	8.95
NLD	CHN	22.16	22.59	17.83	KOR	GBR	26.28	26.79	21.14
NLD	JPN	33.77	34.43	27.17	KOR	NLD	26.00	26.51	20.91
NLD	KOR	27.18	27.71	21.86					

Notes: Average is the mean iceberg cost reductions between all 11 manufacturing sectors, while max and min are the maximum and minimum cost reductions, respectively. Codes: DEU (Germany), FRA (France), GBR (United Kingdom), NLD (Netherlands), CHN (China), JPN (Japan) and KOR (South Korea). Source: Own estimations.

5.3 Additional parameters

The three remaining sets of parameters come from the GTAP model.[24] First, the largest set of parameters are those related to the CDE utility function. To start, the substitution parameters γ_{js} are calculated from the own-price elasticities of substitution. The expansion parameters η_{js} can then be calculated from income elasticities and the γ_{js}. The own-price elasticities are based on spending shares and income elasticities with the income elasticities varying by region and taken from different sources.[25] Second, the substitution elasticities between factor inputs in each of the sectors are based on a review of the empirical literature in the SALTER project (Zeitsch et al., 1991). The values range between 0.25 for agricultural goods and 1.68 for the transport sector. Third, the parameter governing investment reallocation between countries is set at 10, implying that investments are reallocated across countries at a modest rate.

[24] The main characteristics and references to the standard GTAP model can be found at: www.gtap.agecon.purdue.edu/models/current.asp. See also Hertel (2013) and Rutherford and Paltsev (2000) for a more detailed discussion.

[25] See Huff et al. (1997) for further discussion of the sources of the income elasticities and the calibration procedure .

Table 5: Iceberg trade cost reductions for 11 non-services sectors for selected countries.

		iceberg cost reductions					iceberg cost reductions		
From:	To:	average	max	min	From:	To:	average	max	min
DEU	CHN	2.85	4.46	0.62	CHN	DEU	2.68	4.19	0.58
DEU	JPN	4.48	7.03	1.01	CHN	FRA	0.59	0.92	0.12
DEU	KOR	3.54	5.55	0.78	CHN	GBR	2.77	4.35	0.60
					CHN	NLD	2.74	4.30	0.60
FRA	CHN	0.80	1.26	0.17					
FRA	JPN	2.75	4.31	0.60	JPN	DEU	4.46	7.00	1.01
FRA	KOR	1.64	2.56	0.35	JPN	FRA	2.74	4.30	0.60
					JPN	GBR	4.62	7.25	1.05
GBR	CHN	2.94	4.61	0.64	JPN	NLD	4.57	7.16	1.03
GBR	JPN	4.64	7.28	1.05					
GBR	KOR	3.66	5.74	0.81	KOR	DEU	3.36	5.27	0.74
					KOR	FRA	1.42	2.22	0.30
NLD	CHN	2.91	4.56	0.63	KOR	GBR	3.49	5.47	0.77
NLD	JPN	4.59	7.19	1.04	KOR	NLD	3.45	5.41	0.76
NLD	KOR	3.62	5.67	0.80					

Notes: Average is the mean iceberg cost reductions between all 11 manufacturing sectors, while max and min are the maximum and minimum cost reductions, respectively. Codes: DEU (Germany), FRA (France), GBR (United Kingdom), NLD (Netherlands), CHN (China), JPN (Japan) and KOR (South Korea). Source: Own estimations.

5.4 Data

To assess the global general equilibrium effects of the commercial use of the Northern Sea Route, we work with the GTAP9 database with base-year 2011, 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).[26] 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.[27] We aggregate the 57 GTAP sectors into 16 sectors, and the 129 regions into 110 countries (see Table 8 and Table 9 in the Appendix).[28]

[26]These are standard macroeconomic projections used in the related literature. These projections provide the baseline scenario against which our simulations are compared. Hence, the use of a particular baseline scenario will not change qualitatively our main results.

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

[28]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.

6 Counterfactual analysis of reductions in trade costs through the NSR

To assess the global general equilibrium effects of the commercial use of the Northern Sea Route, working from the 2030 projections, our main simulation 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, 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.[29] We also look into the social costs of these trade changes in terms of overall welfare, and employment/wage changes. 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.

6.1 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 0.44%, but global trade volumes increase by 0.21%. 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 5.5%. Of the total Chinese trade in 2030, we project that 14.9% will use the NSR.

Table 6 shows the bilateral trade changes in trade values for goods and services for the main four Northeast 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 Northwestern countries significantly increase their exports to China, Japan and South Korea. This group is compromised of Austria, Belgium, Denmark, Finland, France, Germany, Ireland, 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 Northeast Asia is barely changing or even decreasing for the Mediterranean European countries (i.e. Italy and Greece). 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, Croatia, Hungary, Romania and Slovenia). In Table 10

[29] As explained in Section 5, 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.

Table 6: Northeast Asia, changes in total trade values for selected countries, percentage changes

	China		Japan		South Korea	
	exports	imports	exports	imports	exports	imports
Austria	12.64	10.36	10.97	17.10	8.95	11.78
Belgium	12.34	11.28	15.82	10.82	14.69	11.86
Bulgaria	-1.71	0.69	-0.81	0.41	-1.25	0.16
Croatia	-1.29	0.57	-1.18	-0.01	-0.80	0.20
Czech Republic	8.17	15.44	15.15	18.60	10.49	18.51
Denmark	11.43	9.39	2.64	11.31	5.76	9.19
Estonia	10.75	12.03	9.31	14.55	11.73	6.19
Finland	10.98	6.91	11.77	16.03	10.44	12.49
France	1.51	3.41	9.17	7.81	4.18	6.46
Germany	10.53	10.37	13.88	11.54	7.07	12.58
Greece	-0.99	0.49	-0.45	0.27	-0.72	0.16
Hungary	-2.08	0.50	-1.44	1.09	-1.38	0.89
Ireland	6.56	6.99	3.64	11.78	18.68	8.90
Italy	-1.42	0.97	-1.06	0.17	-0.87	0.30
Latvia	11.37	14.31	5.59	10.34	11.26	11.67
Lithuania	11.03	10.07	9.18	11.36	12.91	7.00
Netherlands	10.62	9.40	14.96	12.98	13.18	12.79
Poland	11.02	13.51	13.64	16.71	9.87	14.71
Portugal	-0.60	0.89	3.16	3.70	3.76	1.36
Romania	-1.79	0.77	-1.25	0.26	-1.25	0.25
Slovakia	7.68	6.06	14.37	9.15	9.66	14.64
Slovenia	-1.59	1.18	-1.05	0.50	-0.82	0.86
Spain	-0.64	0.99	5.50	4.61	1.97	2.12
Sweden	12.70	10.53	13.37	17.97	9.95	12.02
United Kingdom	12.33	8.23	12.30	7.77	7.95	8.98
EU28	6.72	7.48	10.23	9.01	6.49	8.62
Norway	12.63	12.93	12.91	13.20	5.19	10.43
Turkey	-1.31	0.40	-1.03	0.32	-0.81	0.14
United States	-0.72	0.46	-0.58	0.14	-0.30	0.06

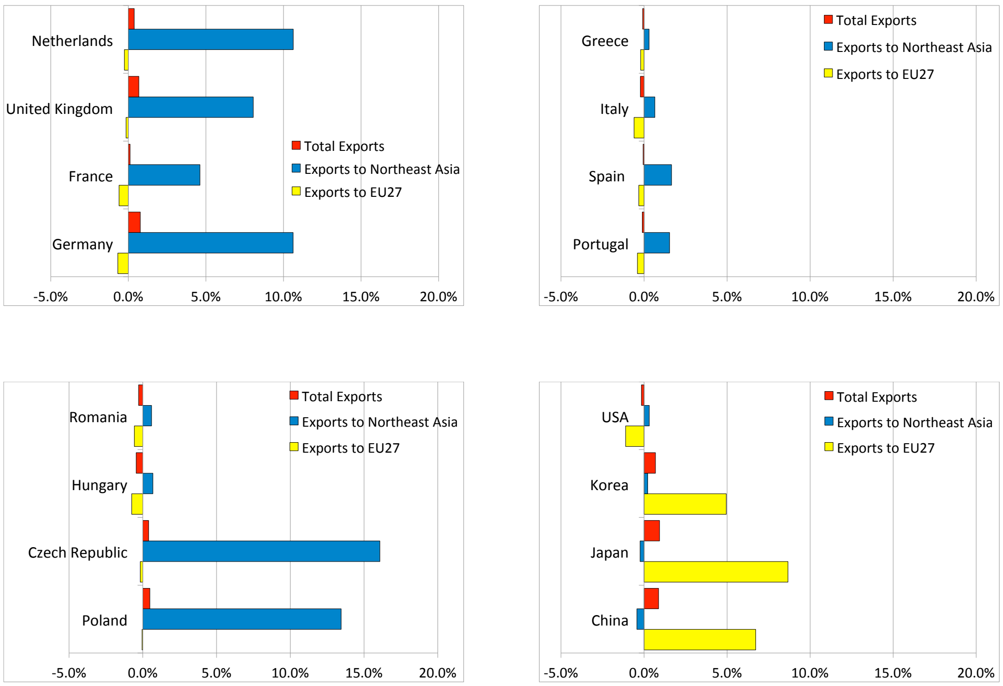
Source: Own estimations using the GTAP database.

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 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 sizeable reduction in intra-European trade, with less trade between Northwestern Europe with South and Eastern Europe. Figure 3 shows these trade diversion patterns.

The precise figures for the countries in Figure 3 and additional countries is presented in Tables11 in the Appendix, were we can clearly observe this trade diversion pattern. First, German trade increases by around 11% to Northeast Asia (i.e.

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



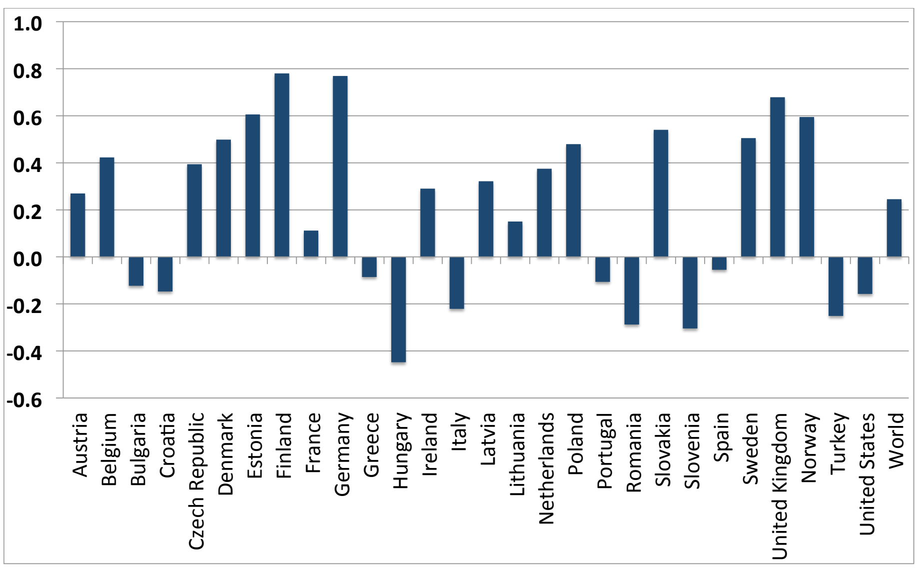
Source: Own estimations using the GTAP database.

Japan, South Korea and China), while trade with other European countries slightly decreasing (by around half percentage point), with Eastern European countries experiencing the biggest decrease of one percentage points. This pattern of changes in German exports is also replicated by the other Northwestern European countries (e.g. Austria, Belgium, Ireland, 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 and the Czech Republic). France, Spain and Portugal also increase their trade with Northeast Asia but at a much lower level rate between 3% and 1%, 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 other Mediterranean countries (Italy, Greece) and Eastern European countries (Hungary, Romania) experience a decrease in trade with both Asia and Europe that is reflected in an overall reduction of trade. Finally, the Northeast Asian countries show that exports increase significantly to Northwestern Europe while experiencing a slight decrease for the rest of the World (RoW).

This pattern of trade diversion can also be seen when we look at exports at the sectoral level. For instance, Tables 12 and 13 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 13 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 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 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 4: Changes in export values for selected countries, percentage changes



Source: Own estimations using the GTAP database.

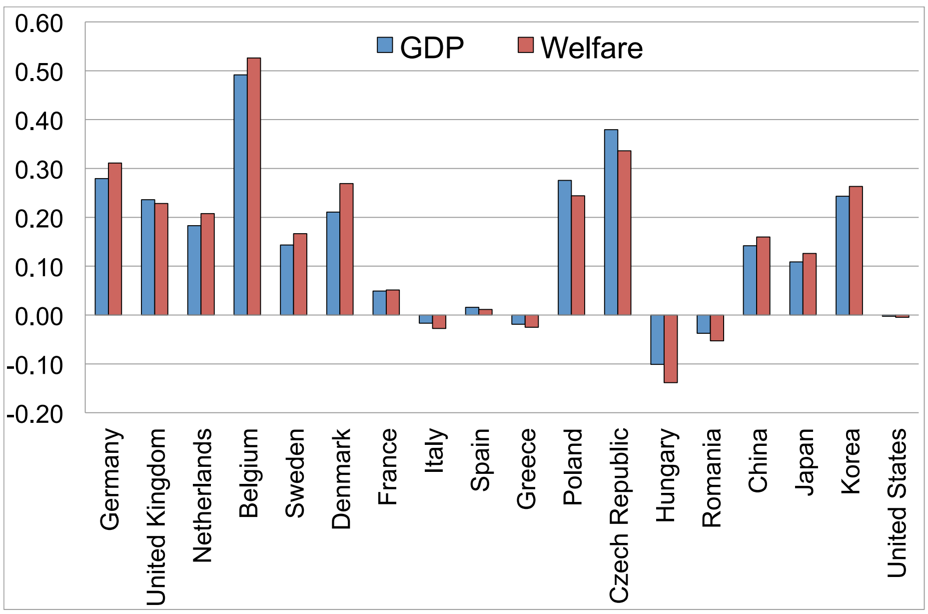
6.2 Macroeconomic outcomes

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).[30] Northeast Asia, Northwestern Europe (and also Poland and the Czech Republic) experience the biggest gains. On the contrary, most South and Eastern

[30]See also Table 14 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$

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.[31]

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



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

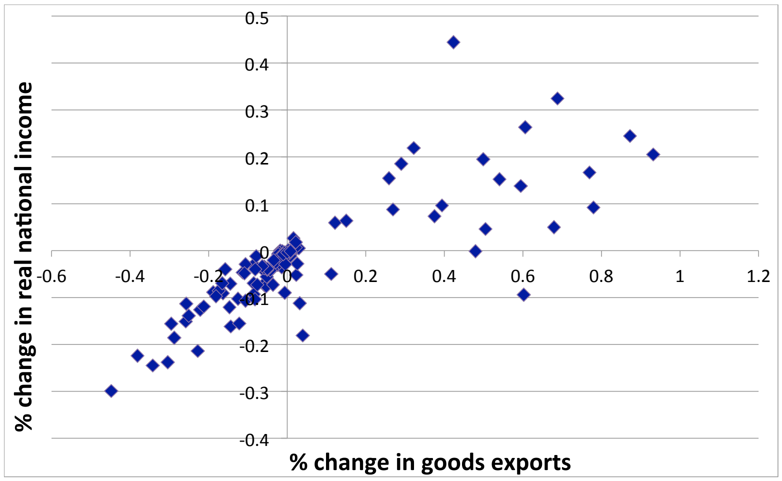
We can observe from Figure 6 that there is a direct relationship between these real income changes and the country-specific changes in exports (and overall trade volumes). In general, countries that increase their exports are those that also benefit from the opening of the NSR. The linkage between trade and welfare gains, therefore, is provided by the use (or not) of the new trade possibilities associated with the NSR. In particular, the positive welfare and GDP effects are driven by the reduction in the transportation and iceberg costs associated with the commercial use of the NSR. The countries that benefit from these trade costs reductions are those that will use intensively the NSR, and by extension, are the same countries that will also increase their trade volumes. On the other hand, countries that do not use the NSR will

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.

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

not benefit from the trade costs reductions and will, in addition, experience trade diversion (increased competition from other countries), which is associated with lower trade, but also with lower welfare and GDP. However, given the relatively small aggregate trade changes, sectoral output follows a similar pattern. We find that much of the sectoral output in most EU countries does not change significantly.[32]

Figure 6: Total export values and real income, percentage changes



Source: Own estimations using the GTAP database.

6.3 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.[33] In the second closure, we assume the labour supply is fixed and the labour market is cleared solely by changes in wages. In general, the changes in wages and employment are closely linked to changes in GDP, which in turn are related to the possibility to benefit from the use of the NSR as explained above.

In Table 15 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 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.[34]

[32]The specific sectoral results are available upon request.
[33]We use a wage curve with an elasticity of 0.2.
[34]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,

From Table 15 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 16 in the Appendix, we observe that on average around 0.5% or less of the total labour force is displaced to another sector. Furthermore, in Table 16 we also present the sectoral changes for low skill workers in three selected sectors. Here we observe that the sectoral displacement is also relatively modest (i.e. less than one percentage points).

Therefore, we do not expect andy medium nor large scale labour adjustment shocks, since the changes in sectoral output and employment will be very modest and will occur gradually according to the speed at which the NSR substitutes for the SSR.

6.4 Changes in CO2 emissions

Regarding CO2 emissions, we use the supplementary emissions data from the GTAP database.[35] CO2 emissions are directly linked in the model to sectoral production and consumption. There are different emission level by sector and increasing (decreasing) the production/consumption of a particular good will increase (decrease) the emissions from that sector. Overall emissions are then defined by the consolidated changes in both sectoral production and consumption. For instance, if more polluting sectors increase production relative to less polluting sectors, then emissions will decrease. This approach assumes that the overall technological links between production, consumption and emissions remain constant, as well as the sector-specific links.[36]

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

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.

[35]The GTAP database regularly incorporates CO2 emissions data from the International Energy Agency (IEA), following UN IPCC guidelines, allocated based on GTAP energy volume data. This involves the Tier 1 method of IPCC Guidelines. See McDougall and Golub (2007) and Lee (2008) for further discussion. The integration of global input-output data with greenhouse gas is an ongoing initiative, supported in part by the EPA and including the MIT Joint Program on the Science and Policy of Global Change. Further information is available here: https://www.gtap.agecon.purdue.edu/models/energy/default.asp.

[36]Projecting future paths of emission technological changes by country and sector pairs is beyond the scope of this paper, so we retain this approximation.

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 14.2 million MT CO2 (see Table 17 in the Appendix). This increase is comparable to the annual emissions for a small countries (e.g. Latvia and Lithuania).[37]

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

7 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.

These shorter shipping distances are associated with substantial reductions in the transportation and trade costs between two major economic regions: Northeast Asia and Northwestern Europe. We estimate that these overall trade costs reductions will increase the trade flows between both regions in average by around 10%, 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 CO2 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 Northeast Asia.

[37]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.

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A Appendix

Table 7: Robustness check: measures of distance and dummies model only

	B_T			CRP			ELE		
	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance
N	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863
pseudo R^2	0.9831	0.9660	0.4902	0.9673	0.9545	0.6572	0.9483	0.9398	0.7698
BIC	1.2e+05	3.5e+05	6.7e+06	2.1e+06	2.9e+06	2.3e+07	1.5e+06	1.7e+06	7.0e+06
	MTL			MVH			OGD		
	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance
N	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863
pseudo R2	0.9734	0.9536	0.6407	0.9564	0.9554	0.6735	0.9812	0.9633	0.5968
BIC	1.7e+06	3.0e+06	2.4e+07	1.6e+06	1.6e+06	1.3e+07	1.7e+06	3.5e+06	3.9e+07
	OMC			PRA			PRE		
	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance
N	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863	11,863
pseudo R2	0.9675	0.9500	0.7274	0.9796	0.9700	0.5013	0.9262	0.9009	0.6320
BIC	2.4e+06	3.8e+06	2.1e+07	8.5e+05	1.3e+06	2.3e+07	2.1e+06	2.8e+06	1.1e+07
	PRF			P_C					
	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance	shipping distance	CEPII distance	no distance
N	11,863	11,863	11,863	11,863	11,863	11,863			
pseudo R2	0.9829	0.9621	0.4559	0.9647	0.9389	0.5144			
BIC	9.2e+05	2.2e+06	3.3e+07	9.4e+05	1.7e+06	1.4e+07			

Notes: PPML estimates, all including source and destination fixed effects and variations on distance controls. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Sector codes: B_T beverages & tobacco; CRP chemicals, rubber, plastics; ELE electrical machinery; MTL metals; MVH motor vehicles; OGD other goods; OMC other machinery; PRA primary agriculture; PRE primary energy; PRF processed foods; P_C petrochemicals.

Table 8: Sectoral description and aggregation

Sector	Code	Sector description	Aggregated GTAP sectors
1	PRA	Primary agriculture	OSD (oil seeds), C_B (sugar cane), PFB (plant-based fibers), OCR (crops nec), CTL (cattle), OAP (animal prods nec), RMK (raw milk), WOL (wool), FSH (fishing), FRS (forestry)
2	PRE	Primary energy	COA (coal), OIL (oil), GAS (gas), OMN (Minerals nec)
3	PRF	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)
4	B_T	Beverages and tobacco	B_T (beverages & tobacco products)
5	P_C	Petrochemicals	P_C (Petroleum and coal products), GDT (gas manufacture and distribution)
6	CRP	Chemicals, rubber, plactics	CRP (Chemical, rubber and plastic products)
7	MTL	Metals	I_S (ferrous metals), NFM (metals nec), FMP (metal products)
8	MVH	Motor vehicles	MVH (motor vehicles and parts)
9	ELE	Electrical machinery	ELE (electronic equipment)
10	OMC	Other machinery	OME (machinery and equipment nec)
11	OGD	Other goods	TEX (textiles), WAP (wearing apparel), LEA (leather products), LUM (wood products), PPP (paper products and publishing), OTN (transport equipment nec), NMM (mineral products nec), OMF (manufactures nec)
12	TRA	Transport	OTP (transport nec), WTP (water transport), ATP (air transport)
13	CNS	Construction	CNS (construction)
14	PSR	Producer services	ELY (electricity), WTR (water), TRD (trade), CMN (communication), OFI (financial services nec), ISR (insurance), OBS (Business services nec)
15	CSR	Consumer services	ROS (recreational and other services), DWE (dwellings)
16	OSG	Public services	OSG (Public Administration, Defense, Education, Health)

Table 9: Country sample

	Code	Country		Code	Country		Code	Country
1	aus	Australia	38	aut	Austria	75	bhr	Bahrain
2	nzl	New Zealand	39	bel	Belgium	76	irn	Iran
3	chn	China	40	cyp	Cyprus	77	isr	Israel
4	jpn	Japan	41	cze	Czech Republic	78	kwt	Kuwait
5	kor	South Korea	42	dnk	Denmark	79	omn	Oman
6	mng	Mongolia	43	est	Estonia	80	qat	Qatar
7	twn	Taiwan	44	fin	Finland	81	sau	Saudi Arabia
8	idn	Indonesia	45	fra	France	82	tur	Turkey
9	mys	Malaysia	46	deu	Germany	83	are	United Arab Emirates
10	phl	Philippines	47	grc	Greece	84	egy	Egypt
11	sgp	Singapore	48	hun	Hungary	85	mar	Morocco
12	tha	Thailand	49	irl	Ireland	86	tun	Tunisia
13	vnm	Viet Nam	50	ita	Italy	87	ben	Benin
14	bgd	Bangladesh	51	lva	Latvia	88	bfa	Burkina Faso
15	ind	India	52	ltu	Lithuania	89	cmr	Cameroon
16	npl	Nepal	53	lux	Luxembourg	90	civ	Cote d'Ivoire
17	pak	Pakistan	54	mlt	Malta	91	gha	Ghana
18	lka	Sri Lanka	55	nld	Netherlands	92	gin	Guinea
19	can	Canada	56	pol	Poland	93	nga	Nigeria
20	usa	United States	57	prt	Portugal	94	sen	Senegal
21	mex	Mexico	58	svk	Slovakia	95	tgo	Togo
22	arg	Argentina	59	svn	Slovenia	96	eth	Ethiopia
23	bol	Bolivia	60	esp	Spain	97	ken	Kenya
24	bra	Brazil	61	swe	Sweden	98	mdg	Madagascar
25	chl	Chile	62	gbr	United Kingdom	99	mwi	Malawi
26	col	Colombia	63	che	Switzerland	100	mus	Mauritius
27	ecu	Ecuador	64	nor	Norway	101	moz	Mozambique
28	pry	Paraguay	65	alb	Albania	102	rwa	Rwanda
29	per	Peru	66	bgr	Bulgaria	103	tza	Tanzania
30	ury	Uruguay	67	blr	Belarus	104	uga	Uganda
31	ven	Venezuela	68	hrv	Croatia	105	zmb	Zambia
32	cri	Costa Rica	69	rou	Romania	106	zwe	Zimbabwe
33	gtm	Guatemala	70	rus	Russian Federation	107	bwa	Botswana
34	hnd	Honduras	71	ukr	Ukraine	108	nam	Namibia
35	nic	Nicaragua	72	arm	Armenia	109	zaf	South Africa
36	pan	Panama	73	aze	Azerbaijan	110	row	Rest of the World
37	slv	El Salvador	74	geo	Georgia			

Table 10: Northeast Asia, changes in trade volumes for goods for selected countries, percentage changes

	China		Japan		South Korea	
	exports	imports	exports	imports	exports	imports
Austria	13.29	14.93	16.65	23.30	11.40	16.54
Belgium	12.50	12.71	17.11	15.95	15.68	16.44
Bulgaria	-1.82	0.75	-1.48	0.28	-1.41	0.10
Croatia	-1.37	0.58	-1.36	-0.10	-0.81	-0.19
Czech Republic	8.25	17.19	17.03	26.17	11.05	21.61
Denmark	11.94	15.29	14.88	19.50	11.03	16.63
Estonia	10.83	16.69	12.09	23.97	12.82	19.86
Finland	11.86	12.63	15.92	23.08	11.76	17.11
France	1.47	4.38	10.38	10.09	4.50	8.08
Germany	10.94	12.12	15.70	16.37	8.50	15.78
Greece	-1.13	0.37	-0.66	-0.17	-0.86	0.07
Hungary	-2.17	0.59	-1.56	0.96	-1.42	0.56
Ireland	12.18	14.39	16.62	18.32	74.44	17.16
Italy	-1.52	1.12	-1.28	0.18	-0.96	0.38
Latvia	11.42	20.67	12.75	30.56	12.21	22.84
Lithuania	11.21	12.12	15.80	24.28	14.06	17.38
Netherlands	11.09	16.06	17.82	24.96	15.48	18.65
Poland	11.15	14.70	14.17	22.41	10.16	18.21
Portugal	-0.69	1.09	6.35	8.80	4.49	5.58
Romania	-1.88	0.88	-1.58	0.26	-1.34	0.32
Slovakia	7.72	6.74	15.52	13.22	9.73	17.58
Slovenia	-1.67	1.47	-1.22	0.53	-0.81	1.18
Spain	-0.73	1.20	7.01	8.31	3.36	4.29
Sweden	13.93	14.72	15.60	22.79	11.54	17.49
United Kingdom	12.83	12.57	15.06	18.31	11.64	15.69
Norway	12.70	13.63	15.85	22.98	5.75	17.22
Turkey	-1.40	0.37	-1.14	0.11	-0.83	0.03
United States	-0.81	0.43	-0.67	0.03	-0.32	-0.11

Source: Own estimations using the GTAP database.

Table 11: 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	-0.5	-0.5	-0.5	-0.3	-0.7	-0.5	-0.1	-0.9	-0.4	-0.5	-0.2	-0.3
South EU	0.0	-0.6	-0.3	0.1	-0.8	-0.3	1.1	-1.0	0.2	-0.1	-0.3	-0.2
East EU	-0.7	-0.2	-0.5	-0.7	-0.8	-0.7	-0.4	-0.5	-0.4	-0.9	0.3	-0.2
NW EU	-0.7	-0.6	-0.7	-0.4	-0.7	-0.6	-0.4	-1.1	-0.7	-0.9	-0.2	-0.5
NE Asia	11.6	11.0	11.2	11.1	12.5	12.0	16.1	8.5	9.4	4.6	2.4	3.1
RoW	0.2	-0.9	-0.2	0.2	-1.1	-0.5	1.3	-1.7	-0.1	0.2	-0.5	-0.1
TOTAL	0.3	0.2	0.3	0.4	0.4	0.4	0.4	0.5	0.4	0.1	0.1	0.1
	Germany			**Greece**			**Hungary**			**Ireland**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	-0.5	-0.6	-0.6	-0.2	0.1	0.0	-0.7	-0.1	-0.4	-0.4	-0.2	-0.3
South EU	0.0	-0.7	-0.3	-0.2	0.0	0.0	0.2	-0.4	-0.1	-0.1	-0.1	-0.1
East EU	-1.0	-0.6	-0.8	-0.5	0.3	0.0	-0.7	0.3	-0.3	-0.7	-0.2	-0.5
NW EU	-0.7	-0.6	-0.7	-0.2	0.1	0.0	-1.1	-0.2	-0.7	-0.6	-0.2	-0.4
NE Asia	10.6	10.0	10.3	0.3	-0.9	-0.5	0.7	-1.9	-1.3	8.6	6.7	7.6
RoW	0.3	-1.1	-0.4	0.0	-0.1	-0.1	0.5	-0.4	0.1	0.2	-0.8	-0.1
TOTAL	0.8	0.9	0.8	-0.1	-0.1	-0.1	-0.4	-0.5	-0.5	0.3	0.3	0.3
	Italy			**Netherlands**			**Poland**			**Portugal**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	-0.5	0.1	-0.2	-0.2	-0.7	-0.4	0.1	-1.3	-0.5	-0.4	-0.1	-0.2
South EU	-0.1	-0.1	-0.1	0.1	-0.7	-0.2	0.7	-1.6	-0.5	-0.1	-0.2	-0.2
East EU	-0.9	0.5	-0.2	-0.6	-0.5	-0.5	-0.1	-1.0	-0.5	-0.9	0.6	-0.1
NW EU	-0.7	0.0	-0.3	-0.3	-0.7	-0.5	-0.2	-1.3	-0.7	-0.6	-0.1	-0.3
NE Asia	0.7	-1.3	-0.8	10.6	10.6	10.6	13.4	10.7	11.0	1.5	0.4	0.8
RoW	0.2	-0.2	0.0	0.2	-1.1	-0.4	0.7	-1.3	-0.4	0.2	-0.2	0.0
TOTAL	-0.2	-0.2	-0.2	0.4	0.4	0.4	0.5	0.4	0.5	-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	-0.4	0.0	-0.2	-0.3	0.0	-0.1	-0.6	-0.6	-0.6	-0.1	-0.9	-0.5
South EU	0.1	-0.3	-0.1	-0.2	-0.1	-0.1	0.1	-0.7	-0.3	0.2	-0.7	-0.4
East EU	-0.6	0.3	-0.1	-0.6	0.6	0.0	-1.2	-0.2	-0.6	-0.5	-1.1	-0.9
NW EU	-1.0	-0.1	-0.5	-0.4	0.0	-0.2	-0.8	-0.6	-0.7	-0.2	-0.9	-0.6
NE Asia	0.6	-1.7	-1.3	1.7	0.1	0.6	11.6	11.7	11.6	8.1	11.3	10.4
RoW	0.2	-0.3	0.0	0.1	-0.2	-0.1	0.1	-0.8	-0.2	0.4	-1.4	-0.6
TOTAL	-0.3	-0.3	-0.3	-0.1	-0.1	-0.1	0.5	0.6	0.5	0.7	0.6	0.6
	China			**Japan**			**Korea**			**USA**		
	exports	imports	trade	exports	imports	trade	exports	imports	trade	exports	imports	trade
Total EU	4.2	7.5	4.9	6.1	9.0	7.1	3.2	8.6	4.7	-0.9	0.4	-0.3
South EU	-1.1	1.0	-0.6	1.5	1.6	1.5	0.2	0.8	0.5	-0.3	0.2	0.0
East EU	5.9	7.1	6.1	9.3	9.3	9.3	8.0	8.3	8.0	-1.6	1.1	-0.1
NW EU	9.1	8.7	9.0	11.8	10.6	11.3	8.0	10.6	9.3	-1.4	0.4	-0.4
NE Asia	-0.4	0.2	-0.1	-0.2	-0.3	-0.3	0.2	-0.4	-0.1	0.3	-0.6	-0.3
RoW	-0.6	0.4	-0.1	-0.4	0.3	0.0	-0.2	0.2	0.0	0.0	0.0	0.0
TOTAL	0.9	1.1	1.0	0.9	0.9	0.9	0.7	0.7	0.7	-0.2	-0.1	-0.1

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 12: 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:													
1 PRA	11.5	10.8	10.2	3.3	11.5	0.3	0.3	10.8	0.6	15.1	11.1	0.4	0.6
2 PRE	10.9	5.7	6.2	4.0	8.6	0.2	0.2	7.6	0.7	8.0	6.9	-0.1	0.0
3 PRF	19.9	18.5	18.1	5.9	19.8	1.0	0.6	19.6	1.3	24.4	18.2	0.2	0.8
4 B_T	-1.4	-0.2	0.1	-0.4	-1.2	0.2	0.2	-1.1	0.1	-1.8	-2.0	0.1	0.2
5 P_C	17.8	22.2	15.2	6.0	22.5	0.6	0.5	24.2	1.3	19.9	38.1	0.2	0.4
6 CRP	11.9	14.6	15.2	3.8	12.8	0.8	0.6	14.1	1.3	11.6	12.3	0.2	0.3
7 MTL	18.1	15.2	17.3	5.2	16.3	1.5	1.1	18.1	1.6	16.6	15.0	0.0	0.2
8 MVH	5.9	6.2	7.3	1.7	5.8	-0.2	-0.3	6.8	0.1	6.1	5.9	-0.6	-0.4
9 ELE	19.5	18.1	20.9	5.5	15.5	2.3	2.1	16.7	2.6	15.7	17.6	-0.2	0.5
10 OMC	18.9	20.6	22.8	6.1	18.8	2.8	2.3	20.6	2.9	19.4	19.8	-0.2	0.3
11 OGD	16.9	15.8	18.2	6.0	17.0	1.2	0.9	14.2	1.5	19.3	17.3	0.2	0.3
12 TSP	0.4	0.4	0.7	0.4	0.4	0.6	0.4	0.5	0.4	0.4	0.5	0.1	0.1
13 CNS	0.8	0.9	1.3	0.8	0.9	1.1	0.9	1.0	0.8	0.8	1.1	0.1	0.1
14 BUS	0.6	0.5	0.9	0.5	0.6	0.7	0.6	0.6	0.5	0.6	0.7	0.1	0.1
15 ROS	1.5	1.1	2.9	1.8	1.9	2.5	2.0	2.0	1.8	1.8	2.1	0.2	0.3
16 OSV	0.5	0.1	0.8	0.6	0.4	0.9	0.7	0.5	0.6	0.5	0.6	0.2	0.1
Simple average	9.6	9.4	9.9	3.2	9.5	1.0	0.8	9.8	1.1	9.9	10.3	0.0	0.2

Notes: The description of each sector is given in Table 8 and country codes are in Table 9.

Source: Own estimations using the GTAP database.

Table 13: Sectoral changes in export sales to Germany for selected countries, percentage changes

	AUT	BEL	CZE	FRA	HUN	ITA	NLD	ESP	SWE	GBR	CHN	JPN	KOR
Sector:													
1 PRA	-0.1	-0.3	-0.2	0.1	0.2	0.1	0.1	0.0	-0.9	0.1	8.9	25.6	13.6
2 PRE	0.3	0.1	0.8	0.4	0.9	0.5	0.3	0.3	0.4	0.5	9.8	18.5	14.6
3 PRF	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.3	15.9	30.9	20.3
4 B_T	0.0	0.4	0.2	-0.1	0.1	0.0	0.3	-0.1	-0.2	0.0	-2.1	-2.1	-2.3
5 P_C	-0.4	-0.2	0.1	-0.4	-0.2	-0.4	-0.2	-0.5	-0.4	-0.1	19.0	29.1	22.8
6 CRP	-0.3	0.0	0.5	-0.2	0.2	-0.2	0.1	-0.4	-0.2	0.3	11.0	15.5	11.3
7 MTL	0.4	0.5	0.6	0.1	0.1	0.0	0.3	0.1	0.2	0.3	15.8	20.4	17.5
8 MVH	-4.5	-4.0	-1.7	-5.1	-5.2	-5.4	-4.4	-5.4	-4.3	-3.5	6.8	11.0	10.2
9 ELE	-2.8	-2.5	-1.2	-3.1	-2.7	-3.3	-2.3	-3.4	-2.7	-2.1	5.0	12.6	7.2
10 OMC	-1.3	-1.0	-0.8	-1.3	-1.0	-1.3	-1.1	-1.4	-1.3	-0.9	12.6	16.8	7.1
11 OGD	0.2	0.1	0.5	0.2	0.3	0.2	0.2	0.2	0.2	0.2	12.4	18.5	15.8
12 TSP	0.4	0.4	0.8	0.3	0.6	0.4	0.5	0.3	0.3	0.7	-0.1	-0.2	-0.1
13 CNS	0.3	0.2	0.6	0.2	0.4	0.2	0.3	0.2	0.2	0.3	-0.3	-0.3	-0.4
14 BUS	-0.1	-0.5	1.3	0.2	0.9	0.4	0.4	0.2	0.2	0.5	-0.2	-0.2	-0.2
15 ROS	0.2	-0.2	0.5	0.3	0.6	0.4	0.3	0.3	0.3	0.4	-1.5	-1.4	-1.3
16 OSV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	-0.2
Simple average	-0.5	-0.4	0.1	-0.5	-0.3	-0.5	-0.3	-0.6	-0.5	-0.2	7.0	12.2	8.5

Notes: The description of each sector is given in Table 8 and country codes are in Table 9.

Source: Own estimations using the GTAP database.

Table 14: CGE results on GDP, real income and welfare

	GDP index	Real Income	Welfare (per capita utility) % changes	Welfare (equivalent variation in US$ million)
Austria	0.19	0.09	0.20	1,062
Belgium	0.49	0.44	0.53	3,460
Bulgaria	-0.04	-0.16	-0.05	-49
Croatia	-0.02	-0.12	-0.03	-20
Czech Republic	0.38	0.10	0.34	1,182
Denmark	0.21	0.19	0.27	1,101
Estonia	0.46	0.26	0.42	157
Finland	0.14	0.09	0.17	587
France	0.05	-0.05	0.05	1,794
Germany	0.28	0.17	0.31	13,049
Greece	-0.02	-0.09	-0.02	-83
Hungary	-0.10	-0.30	-0.14	-242
Ireland	0.25	0.19	0.30	900
Italy	-0.02	-0.13	-0.03	-673
Latvia	0.41	0.22	0.40	186
Lithuania	0.28	0.06	0.24	163
Netherlands	0.18	0.07	0.21	2,153
Poland	0.28	0.00	0.24	1,985
Portugal	0.01	-0.11	0.00	-5
Romania	-0.04	-0.19	-0.05	-152
Slovakia	0.48	0.15	0.39	591
Slovenia	-0.06	-0.24	-0.10	-63
Spain	0.02	-0.08	0.01	189
Sweden	0.14	0.05	0.17	1,313
United Kingdom	0.24	0.05	0.23	7,489
Norway	0.17	0.14	0.23	1,547
Turkey	-0.03	-0.14	-0.04	-686
China	0.14	0.24	0.16	38,519
Japan	0.11	0.20	0.13	8,142
Korea	0.24	0.32	0.26	4,881
United States	0.00	-0.04	0.00	-1,021
Total (World)	0.06	0.05	0.07	88,107

Source: Own estimations using the GTAP database.

Table 15: CGE results for the labour market, real wages and total employment changes for three skill levels, percentage changes

	Changes in real wages						Changes in total employment		
	fixed labour supply			flexible labour supply			flexible labour supply		
	low skill	med skill	high skill	low skill	med skill	high skill	low skill	med skill	high skill
Austria	0.21	0.17	0.19	0.21	0.17	0.19	0.04	0.03	0.04
Belgium	0.64	0.52	0.57	0.58	0.48	0.53	0.12	0.10	0.11
Bulgaria	-0.08	-0.06	-0.07	-0.08	-0.06	-0.07	-0.02	-0.01	-0.01
Croatia	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.01	-0.01	-0.01
Czech Republic	0.24	0.24	0.25	0.24	0.23	0.24	0.05	0.05	0.05
Denmark	0.35	0.25	0.26	0.33	0.24	0.26	0.07	0.05	0.05
Estonia	0.44	0.36	0.41	0.40	0.33	0.37	0.08	0.07	0.07
Finland	0.19	0.15	0.14	0.18	0.14	0.13	0.04	0.03	0.03
France	0.07	0.04	0.04	0.07	0.04	0.04	0.01	0.01	0.01
Germany	0.33	0.27	0.28	0.32	0.26	0.27	0.06	0.05	0.05
Greece	-0.01	-0.03	-0.04	-0.01	-0.03	-0.04	0.00	-0.01	-0.01
Hungary	-0.21	-0.15	-0.16	-0.19	-0.14	-0.15	-0.04	-0.03	-0.03
Ireland	0.31	0.23	0.29	0.30	0.23	0.28	0.06	0.05	0.06
Italy	-0.03	-0.04	-0.03	-0.02	-0.03	-0.03	0.00	-0.01	-0.01
Latvia	0.29	0.32	0.31	0.28	0.30	0.30	0.06	0.06	0.06
Lithuania	0.25	0.20	0.20	0.23	0.19	0.19	0.05	0.04	0.04
Netherlands	0.24	0.21	0.23	0.24	0.20	0.23	0.05	0.04	0.05
Poland	0.16	0.16	0.18	0.15	0.15	0.17	0.03	0.03	0.03
Portugal	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.00
Romania	-0.06	-0.08	-0.08	-0.06	-0.07	-0.07	-0.01	-0.01	-0.01
Slovakia	0.24	0.27	0.30	0.23	0.25	0.28	0.05	0.05	0.06
Slovenia	-0.09	-0.11	-0.12	-0.09	-0.10	-0.11	-0.02	-0.02	-0.02
Spain	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Sweden	0.17	0.14	0.14	0.17	0.14	0.14	0.03	0.03	0.03
United Kingdom	0.20	0.22	0.21	0.20	0.21	0.20	0.04	0.04	0.04
Norway	0.21	0.15	0.16	0.20	0.15	0.16	0.04	0.03	0.03
Turkey	-0.03	-0.06	-0.06	-0.03	-0.06	-0.06	-0.01	-0.01	-0.01
China	0.13	0.13	0.15	0.11	0.12	0.13	0.02	0.02	0.03
Japan	0.15	0.12	0.14	0.14	0.12	0.13	0.03	0.02	0.03
Korea	0.32	0.28	0.31	0.30	0.27	0.29	0.06	0.05	0.06
United States	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00

Notes: By construction, total employment does not change in the fixed labour supply scenario.

Source: Own estimations using the GTAP database.

Table 16: CGE results for the labour market, labour displacement and employment changes for low skill workers in selected sectors, percentage changes

	Labour displacement			Sectoral employment changes		
	flexible labour supply			low skill, flexible labour supply		
	low skill	medium skill	high skill	Motor vehicles	Metals	Other manuf.
Austria	0.25	0.21	0.01	0.41	0.20	-0.11
Belgium	0.35	0.30	0.04	0.28	0.32	-0.64
Bulgaria	0.14	0.09	0.02	-0.08	-0.29	-0.17
Croatia	0.08	0.07	0.01	-0.19	-0.03	-0.12
Czech Republic	0.21	0.17	0.03	0.10	0.23	-0.27
Denmark	0.65	0.41	0.07	-0.15	-0.13	-1.10
Estonia	0.44	0.35	0.04	-0.20	0.24	-0.58
Finland	0.39	0.21	0.05	-0.04	0.21	-0.06
France	0.14	0.10	0.01	-0.15	-0.02	-0.19
Germany	0.35	0.25	0.03	0.54	0.29	-0.77
Greece	0.07	0.04	0.00	-0.14	-0.08	-0.10
Hungary	0.36	0.24	0.04	0.11	0.18	0.00
Ireland	0.33	0.22	0.17	-0.38	-0.43	-0.98
Italy	0.08	0.04	0.02	-0.14	0.01	-0.08
Latvia	0.74	0.44	0.05	0.00	0.26	-0.48
Lithuania	0.34	0.22	0.04	0.05	0.37	-0.38
Netherlands	0.51	0.34	0.08	0.05	0.62	-1.14
Poland	0.42	0.28	0.01	0.06	0.57	-0.37
Portugal	0.12	0.07	0.02	-0.08	0.05	-0.13
Romania	0.11	0.07	0.01	-0.07	0.10	-0.06
Slovakia	0.49	0.34	0.06	1.33	-0.04	-0.28
Slovenia	0.19	0.16	0.01	-0.11	0.10	-0.10
Spain	0.12	0.06	0.02	-0.21	-0.01	-0.10
Sweden	0.32	0.21	0.01	0.04	0.54	-0.41
United Kingdom	0.34	0.24	0.04	0.34	0.65	-0.93
Norway	0.50	0.27	0.02	-0.49	0.58	-0.81
Turkey	0.05	0.02	0.00	-0.13	0.03	-0.11
China	0.13	0.10	0.01	-0.53	-0.09	0.21
Japan	0.17	0.08	0.01	0.09	0.01	-0.08
Korea	0.21	0.17	0.01	-0.05	-0.21	-0.07
United States	0.03	0.01	0.00	-0.03	0.01	0.02

Notes: Labour displacement is the weighted standard deviation of the sectoral changes.

Source: Own estimations using the GTAP database.

Table 17: CGE results on CO2 emissions for selected countries

	CO2 emission changes (MT)	CO2 emission % changes	Benchmark CO2 levels (projections in 2030)	share in 2030 projections
Austria	0.05	0.06	72	0.2%
Belgium	0.44	0.37	117	0.3%
Bulgaria	-0.01	-0.02	67	0.2%
Croatia	-0.01	-0.03	19	0.0%
Czech Republic	0.26	0.19	132	0.3%
Denmark	0.00	0.00	77	0.2%
Estonia	0.08	0.40	21	0.0%
Finland	0.01	0.01	60	0.1%
France	0.13	0.03	413	1.0%
Germany	0.93	0.14	685	1.6%
Greece	-0.08	-0.04	207	0.5%
Hungary	-0.03	-0.07	48	0.1%
Ireland	0.08	0.15	52	0.1%
Italy	-0.17	-0.04	403	0.9%
Latvia	0.03	0.23	13	0.0%
Lithuania	0.01	0.11	14	0.0%
Netherlands	0.32	0.17	190	0.4%
Poland	0.49	0.14	359	0.8%
Portugal	-0.02	-0.03	57	0.1%
Romania	-0.03	-0.03	98	0.2%
Slovakia	0.10	0.27	37	0.1%
Slovenia	-0.02	-0.09	18	0.0%
Spain	-0.07	-0.02	303	0.7%
Sweden	0.06	0.10	56	0.1%
United Kingdom	1.01	0.19	522	1.2%
Norway	0.00	0.00	75	0.2%
Turkey	-0.19	-0.04	441	1.0%
China	12.13	0.09	13,055	30.7%
Japan	0.68	0.07	1,039	2.4%
Korea	0.69	0.11	658	1.5%
United States	-0.63	-0.01	6,052	14.2%
Total (World)	14.23	0.06	25,361	100.0%

Source: Own estimations using the GTAP database.

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