Impacts of Trade Facilitation on Modal Choice in International Trade

by

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December 20, 2015

Abstract

Over the last decade global trade carried via air transport has grown drastically, which is partially due to the increasing demand for 'just in time' delivery of intermediate goods as well as due to the growing importance of trade between more distant countries.

In this paper we analyze the effect of trade facilitation or improved logistics on transport mode choice in international trade. For this purpose we develop a continuous modal choice model, which produces a composite transportation service using a mix of air-land or air-water transportation inputs. We then estimate the associated elasticities of substitution between transport modes. We find that modal substitution elasticities have a typical value of 0.9 to 2.8.

The quality of logistics infrastructure is also estimated to alter modal choice in international trade. In order to draw out the implications of these empirical findings for global trade patterns, international transport use, and regional economic welfare, we then incorporate the modal choice model into the Global Trade Analysis Project (GTAP) model of global trade. Not surprisingly, we find that improvement in logistics reduces the overall cost of transport and amount of services required to transport a given product along a given route by a given mode. Also, the reduction in modal cost of transport results in modal substitution. We find that in some regions improvement in logistics increases the use of air transport, while in others it reduces the demand for both air and water transportation, having a larger negative effect on maritime transport and, thus, resulting in a relatively increased use of air transportation.

JEL category: R41, F13

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Introduction

Over the last decade the use of international transport has increased sharply due to the growing portion of trade carried via air transport. This growth has been stimulated by the increasing demand for 'just in time' delivery of intermediate goods and by the increasing importance of trade between countries without common borders (Cristea et al., 2013).

Global trade facilitation has significant impact on the choice of transport mode in international trade. Trade facilitation considers range of activities that improve trading capacities of various countries. Wilson et al. (2003) define facilitation of trade as the improvement in logistics at both customs and ports of entry as well as the development of more efficient administration and procedures. Since the trade facilitation depends extensively on international transport, it becomes very important to understand how the improvement in logistics will affect the choice of transport mode and the overall volume of international trade.

We begin our analysis by estimating elasticities of substitution between different modes of transport using the Latin American trade data available from Hummels et al. (2009). The estimated elasticity of substitution governs modal choice changes in response to changes in the relative cost of the different transport options. In a second stage, these modal choice elasticities are incorporated into the Global Trade Analysis Project (GTAP) general equilibrium model in order to investigate the impacts of improved logistics on modal choice and overall trade volumes.

Literature review

The empirical literature on trade facilitation is addressed in a narrow sense. Most of the studies focus on trade impacts of trade facilitation placing less emphasis on its modal choice effects. Robert et al. (2014) find a link between trade facilitation and export variety for a broad cross-section of countries. In this study trade efficiency is measured using port efficiency and bilateral import tariffs. Using an empirical gravity model for 228 countries over 1960-2006 the authors show that port efficiency contributes significantly to the extensive margin of exports, while bilateral import tariff negatively affects the variety of exports.

Hoekman et al. (2010) analyze the effects of trade facilitation on trade volumes. They model trade facilitation as tariff reduction for different groups of the World Trade Organization (WTO) members, such as developing countries, developed countries and a small group of countries that were recently acceded to WTO. The study focuses on agriculture and non-agriculture markets and shows that even a small reduction in trade costs generates larger trade effects.

Some studies show that non-price factors can also have significant impact on the facilitation of trade. Bourdet et al. (2014) focus on the number of days it takes to comply with all relevant import procedures in the European Union and non-European Union countries, and show that it depends on the trade facilitation methods, such as documentation, preparation, customs clearance and technical control, parts and terminal holding, inland transportation and holding. They also include additional explanatory variables for GDP, GDP per capita, and the distance between the large cities of trading countries. The authors then establish a gravity equation on bilateral imports and show that trade facilitation increases export volumes and export diversification.

Marti et al. (2014) discuss the importance of Logistic Performance Index (LPI), which is a good proxy of trade facilitation. The authors develop a gravity model for trade flows in emerging markets. They aggregate all countries to five emerging geographical regions: South

America, Middle East, Africa, Far East and post-Soviet State. In addition, goods are classified according to the complexity of their transportation to determine the impacts of logistics on the transported freight. All the goods are aggregated to five categories: goods with no logistic problems (textiles, food), goods with few logistic problems (fertilizer, mineral, and livestock), goods with conventional logistic problems (aluminum, zinc, and other food which require refrigerator), goods with complex logistic problems (machinery, engines), and goods with highly complex logistics problems. The authors define independent variables for GDP, population, LPI, and the distance between both countries. According to their findings, the LPI is most important for Middle Eastern exports, which include commodities that are more difficult to transport. In case of importing countries, LPI plays a less prominent role in trade flows.

Dennis (2010) discusses the role of trade facilitation during the period of Economic downturn. The study uses a gravity model with standard gravity variables, such as per capita income, GDP, distance, common language, and common border over the 2008-2009 period. The author finds that countries with better trade facilitation environment experienced less reduction in their exports to the United States compared to those with a weaker trade facilitation environment. In addition, an extra day delay in exporting country generates about 0.5% more reduction in the U.S. import demand.

Felipe et al. (2012) estimate trade gains of improved trade facilitation in the Central Asian countries, which are ranked the lowest in terms of LPI. The results show that on the exporter side infrastructure has the greatest impact on trade flows. They also find that on the importer side customs efficiency has the largest impact on trade.

A number of studies analyze macroeconomic and trade impacts of trade facilitation using Computable General Equilibrium (CGE) models. Zaki (2014) analyzes both short and long term effects of trade facilitation using a multi-regional and multi-sectoral CGE model. The study uses the GTAP 7 database to analyze two scenarios. The first scenario captures the effect of partial removal of administrative barriers assuming 50% reduction in trade costs for all countries, while the second simulation introduces a tariff shock of the same proportion. The results show that the long-run welfare effects of trade facilitation are much higher than the short-run impacts. In addition, gains from trade facilitation are more significant for developing economies. Furthermore, trade facilitation improves export diversification leading to an expansion of sectors that are more sensitive to time, such as, food, textiles, and electronics.

In a recent study, Avetisyan et al. (2015) analyze the macroeconomic and trade effects of improved customs processing through reduced wait times at major northern and southern land freight crossings of the U.S. The reduction in wait time stems from increased staffing at land ports of entry, which is then translated into reduction in truck transport costs through a logistical model. The results show that an increase in the number of inspection agents at U.S northern and southern land border crossings will increase the U.S. GDP, employment and trade volumes mainly through growing imports of intermediate goods and more competitive U.S. exports of final consumption goods.

Cristea et al. (2013) evaluate changes in international transport use and related GHG emissions stemming from trade liberalization and unequally distributed GDP increases. Using a general equilibrium framework the authors first simulate a liberalization of the world trade system by changing all import and export tariffs and subsidies. In the second exercise, uneven GDP growth is simulated to generate changes in output and exports. The study then converts changes in trade values to weights that can be linked to the use of transport. Drawing on a wide-spread data pool on the movement of traded goods between countries, the study translates an increase in weight-distance trade into growth in modal usage. The authors assume fixed modal shares of air and water transport to allow for compositional changes in modal use without formally modeling choice of transport mode. As the authors mention, their research does not focus on modal choice and how that would affect changes in trade patterns. The authors show that both trade liberalization and GDP growth negatively affect the global use of road and rail transport, while significantly expanding air and water transport modes.

In this paper we analyze the effect of trade facilitation or improved logistics on the choice of transport mode and the overall volume of international trade. For this purpose we estimate the elasticities of substitution between air, water and land transport modes and develop a continuous modal choice model that produces a composite transportation service using a mix of air-land or air-water transportation inputs.

Estimating elasticities of modal substitution

In this section, we focus on pair-wise modal choice decisions in order to facilitate estimation without overly restricting substitution possibilities amongst modes, and due to the fact that some countries do not trade by sea and some do not trade by land. We use a Constant Elasticity of Substitution (CES) production function to generate an aggregate transportation input representing the combination of either air and land, or air and water, transport. Depending on geographic location (land and non-land) we can represent transportation from region r to s as a CES production function (e.g., for land-air substitution) with two inputs – land and air transport:

$$Q_{i,r,s}^{TRANSPORT} = F^{l} * [\alpha * A_{i,r,s}^{-\rho} + \beta * L_{i,r,s}^{-\rho}]^{-\frac{1}{\rho}}, \ \rho = \frac{1-\sigma_i^l}{\sigma_i^l} \quad (1)$$

In case of water-air substitution the transportation from region r to s can be represented as a CES production function with two inputs – water and air transport:

$$Q_{i,r,s}^{TRANSPORT} = F^{nl} * [\delta * A_{i,r,s}^{-\tau} + \varphi * W_{i,r,s}^{-\tau}]^{-\frac{1}{\tau}},\ \tau = \frac{1-\sigma_i^{nl}}{\sigma_i^{nl}} \quad (2)$$

where,

$Q_{i,r,s}^{TRANSPORT}$ – Total transportation required to ship good *i* from region *r* to *s*;

F^{l}, F^{nl} - Factor productivity;

α, β, δ, φ – Distribution parameters;

$\sigma_i^{l}, \sigma_i^{nl}$ – Elasticities of substitution for land-air and water-air transport for good *i*;

$A_{i,r,s}$ – Air transport required to ship good *i* from region *r* to *s*;

$L_{i,r,s}$ – Land transport required to ship good *i* from region *r* to *s*;

$W_{i,r,s}$ – Water transport required to ship good *i* from region *r* to *s*.

The detailed derivation of the modal substitution model is available in the Appendix A. Using expression (10) from the Appendix A we obtain the following log-linear equations for modal substitution:

$$\log\alpha - \log\beta + \frac{1}{\sigma_i^{l}} * (\log L_{i,r,s} - \log A_{i,r,s}) = \log P_{i,r,s}^{A} - \log P_{i,r,s}^{L} \quad (3)$$

$$\log\delta - \log\varphi + \frac{1}{\sigma_i^{nl}} * (\log W_{i,r,s} - \log A_{i,r,s}) = \log P_{i,r,s}^{A} - \log P_{i,r,s}^{W} \quad (4)$$

These may be rearranged to permit estimation of σ_i^{l} and σ_i^{nl} using the following two expressions:

$$\log\frac{L_{i,r,s}}{A_{i,r,s}} = -\sigma_i^{l} * \log\frac{\alpha}{\beta} + \sigma_i^{l} * \log\frac{P_{i,r,s}^{A}}{P_{i,r,s}^{L}} \quad (5)$$

$$\log\frac{W_{i,r,s}}{A_{i,r,s}} = -\sigma_i^{nl} * \log\frac{\delta}{\varphi} + \sigma_i^{nl} * \log\frac{P_{i,r,s}^{A}}{P_{i,r,s}^{W}} \quad (6)$$

where:

$P_{i,r,s}^{A}$, $P_{i,r,s}^{L}$, and $P_{i,r,s}^{W}$ – prices of air, land and water transport to ship good *i* from region *r* to *s*.

In equations (5) and (6) the distribution parameters depend on a number of factors such as quality of infrastructure, customs efficiency, etc. If the land and maritime transport infrastructure of a country has functional limitations, including geographic constraints (e.g., no access to the sea), limitations on physical design of the container yards and freight stations, and/or a poor internal road system, then we would expect the demand for air transport to be relatively more dominant as this may be the only way to obtain timely export/import of products. Therefore, in estimating these equations we need to focus on both the elasticities of modal substitution as well as the distribution parameters.

Claro (2002) suggests a methodology for estimating the CES elasticity of substitution between two production inputs (labor and capital) when the distribution parameters vary across regions. The author assumes that distribution parameters vary across regions, while the elasticity of substitution is invariant. Claro (2002) combines the first order conditions of the profit maximization process to derive a relationship between relative factor prices and their intensities at the sectoral level. With a common vector of relative factor prices, various sectors use different techniques of production (without a theory of cross-industry factor price variations). In estimating the substitution elasticities, the author considers the factor price variations at the sectoral level.

In the case of modal substitution in international transport, we have information about how the quality of logistics infrastructure varies across countries, and we hypothesize that this index will influence the choice of international transport mode. Accordingly, we replace the first terms in our estimation equations (5) and (6) with the LPI developed by the World Bank[1], which is available for 150 countries and accounts for the effects of the following seven factors:

1. Customs and other border agencies clearance effectiveness.
2. Transport and information technology infrastructure quality for logistics.
3. Easiness and reasonable pricing of international shipments.

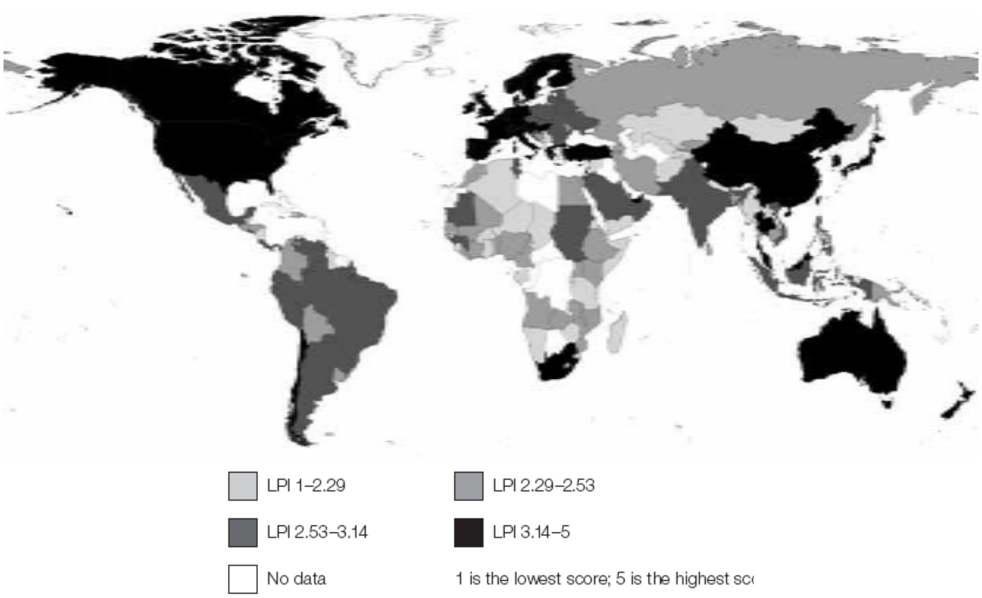
[1] See Arvis et al. (2007)

4. Proficiency of the domestic logistics.
5. Tracking capabilities for international shipments.
6. Cost of the local logistics.
7. Timely shipping to destination.

As indicated by Arvis et al. (2007), domestic costs are found to be uncorrelated with other LPI factors. Therefore, this component is excluded from the composition of the index allowing us to account for exporter and importer non-price logistics effects.

Generally, developed countries have a higher LPI, but there are large variations across developing regions with similar income levels. For instance, China, being a medium income country, scores 30th of 150 countries, whereas higher income oil producing regions show lower LPI. In developing countries, such as upper middle income countries South Africa, Malaysia, Chile and Turkey, lower middle income countries China and Thailand, and low income countries India and Vietnam, where trade is a significant factor facilitating growth, the LPI is relatively higher than in other regions with similar income levels. Figure 1 shows the global distribution of LPI.

Figure 1. Distribution of LPI across world countries



Source: Arvis et al. (2007)

Since we need control for both exporter and importer logistics effects, we consider the product of the two partners' LPIs as the most relevant measure of logistics quality along any given bilateral route. Therefore, in equations (5) and (6) we introduced the natural logarithm of the product of export and import country LPI, hypothesizing that a larger composite LPI will generate a bias towards air transport. But there may be countries that produce high value products and need better logistics infrastructure to provide fast delivery of such goods using air transport. Moreover, increasing demand for 'just in time' delivery of intermediate goods may also increase the air transport demand. Therefore, it is possible to have product and country pairs for which growing LPI increases the demand for air transport. This results in the following final estimation equations:

$$\log\frac{L_{i,r,s}}{A_{i,r,s}} = k_{0,i}^{l} - k_{1,i}^{l} * \log LPI_r * LPI_s + \sigma_i^{l} * \log\frac{P_{i,r,s}^{A}}{P_{i,r,s}^{L}} + u_{i,r,s} \qquad (7)$$

$$\log\frac{W_{i,r,s}}{A_{i,r,s}} = k_{0,i}^{nl} - k_{1,i}^{nl} * \log LPI_r * LPI_s + \sigma_i^{nl} * \log\frac{P_{i,r,s}^{W}}{P_{i,r,s}^{L}} + v_{i,r,s} \qquad (8)$$

Data and estimates of modal substitution elasticities

We use Latin American Integration Association (ALADI) trade data available from Hummels et al. (2009). The data set is available at HS 6 commodity level and includes the freight and insurance values and quantities for the same trade flows from 229 countries to 11 Latin American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela). We also use the Logistics Performance Index for 150 countries available from the World Bank.

There are two interesting options for estimation. First, we can aggregate the HS 6 commodity level freight and insurance values and quantities based on the GTAP merchandise commodity grouping presented in Table 1. The benefit for such aggregation would be the precision of matching it with the data variation in the GTAP data base – a single freight and insurance value and quantity for each bilateral region pair corresponding to each merchandise commodity. While with the second technique we preserve the variation across HS 6 level commodities and origin-destination pairs within every GTAP sector, and by such approach we restrict the modal substitution elasticity to be the same within each GTAP sector. We generate our estimates using the second approach, which enables us to retain the variation of freight and insurance values and quantities within each broad GTAP sector and generate more accurate estimates of modal substitution elasticities.

To estimate the elasticities of modal substitution we apply the Ordinary Least Squares (OLS) method to expressions (7) and (8). All estimated elasticities are positive, as reported in Table 1. This table also reports the estimated standard errors. For all elasticities, we reject the null hypothesis that the estimated modal substitution elasticity is zero at the 95% confidence level.

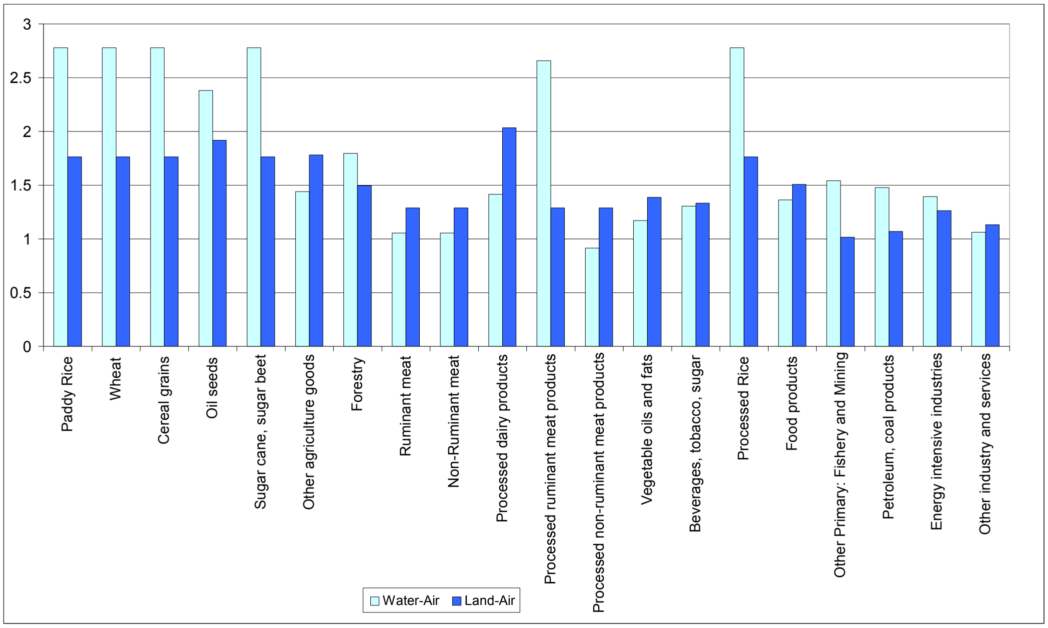
The results of our estimation are summarized in Table 1. It should be noted that, due to data availability the modal substitution elasticities in the cereal grains sector are used as proxies for the paddy rice, wheat, sugar cane, and processed rice sectors. For the ruminant meat sector we use the estimated elasticities from the non-ruminant meat sector. Finally, for the substitution between land and air transport in the processed ruminant and non-ruminant meat products sectors we use the estimated land-air elasticity of substitution for the non-ruminant meat sector.

Table 1. Water-air and land-air transportation elasticities of substitution

Sectors	Water-Air		Land-Air	
	Elasticity of substitution	Standard Deviation	Elasticity of substitution	Standard Deviation
Paddy Rice	2.779	0.40	1.762	0.40
Wheat	2.779	0.40	1.762	0.40
Cereal grains	2.779	0.40	1.762	0.40
Oil seeds	2.383	0.32	1.917	0.59
Sugar cane, sugar beet	2.779	0.40	1.762	0.40
Other agriculture goods	1.441	0.10	1.780	0.15
Forestry	1.795	0.23	1.494	0.41
Dairy farms	N/A	N/A	N/A	N/A
Ruminant meat	1.055	0.32	1.288	0.37
Non-Ruminant meat	1.055	0.32	1.288	0.37
Processed dairy products	1.416	0.23	2.032	0.27
Processed ruminant meat products	2.657	0.57	1.288	0.37
Processed non-ruminant meat products	0.914	0.21	1.288	0.37
Vegetable oils and fats	1.171	0.23	1.387	0.35
Beverages, tobacco, sugar	1.303	0.13	1.333	0.14
Processed Rice	2.779	0.40	1.762	0.40
Food products	1.364	0.05	1.507	0.07
Other Primary: Fishery and Mining	1.540	0.10	1.014	0.21
Coal	N/A	N/A	N/A	N/A
Crude Oil	N/A	N/A	N/A	N/A
Natural gas	N/A	N/A	N/A	N/A
Petroleum, coal products	1.477	0.14	1.071	0.22
Electricity	N/A	N/A	N/A	N/A
Energy intensive industries	1.395	0.01	1.262	0.02
Other transport	N/A	N/A	N/A	N/A
Water transport	N/A	N/A	N/A	N/A
Air transport	N/A	N/A	N/A	N/A
Other industry and services	1.062	0.01	1.131	0.01

As we can see from Table 1, the modal substitution elasticities for both water-air and land-air pairs are higher in agricultural sectors. This may be due to the greater degree of disaggregation in these sectors. For illustrative purposes we also plot water-air and land-air elasticities of substitution by sector (Figure 2).

Figure 2. Comparison of water-air and land-air elasticities of substitution by sector



Our estimates of the LPI coefficients are statistically significant for some sectors and are typically negative. Thus, with growing LPI in these sectors the demand of air transport for international shipping will increase. As previously mentioned, one explanation for such outcome is that regions that have a lot of high value products need better transport infrastructure to get them out quickly. This may also be stimulated by the growing demand for 'just in time' delivery of intermediate goods using the fastest air transport mode. Table 2 shows the estimated coefficients and standard errors for the sectors with statistically significant LPI.

Table 2. LPI for water-air and land-air transportation pairs

Sectors	Water-Air		Land-Air	
	LPI coef.	St. Dev.	LPI coef.	St. Dev.
Cereal grains	-6.095	2.75	-	-
Other agriculture goods	-2.701	0.87	-4.276	1.76
Processed dairy products	-	-	-11.018	3.20
Processed non-ruminant meat products	-	-	-22.586	4.84
Vegetable oils and fats	-	-	-9.765	3.59
Beverages, tobacco, sugar	-	-	-6.017	1.57
Food products	-0.866	0.38	-8.412	0.72
Other Primary: Fishery and Mining	-	-	-8.944	2.97
Petroleum, coal products	-5.411	1.58	-12.235	2.42
Energy intensive industries	-0.862	0.10	-7.033	0.17
Other industry and services	-1.500	0.08	-5.312	0.11

Modal substitution in GTAP

We use the estimated elasticities to introduce transport modal substitution to the Global Trade Analysis Project computable general equilibrium model described in Hertel (1997). To derive the modal substitution we develop similar cost minimization problem for the aggregate transport production. The shipment of good *i* from region *r* to *s* can be represented as a CES production function with three inputs – air, water, and other transport:

$$Q_{i,r,s}^{TRANSPORT} = F*[\alpha * Q_{i,r,s}^{AIR-\rho} + \beta * Q_{i,r,s}^{WATER-\rho} + \gamma * Q_{i,r,s}^{OTHER-\rho}]^{-\frac{1}{\rho}}, \rho = \frac{1-\sigma_i}{\sigma_i} \quad (9)$$

where:

$Q_{i,r,s}^{AIR}$, $Q_{i,r,s}^{WATER}$, $Q_{i,r,s}^{OTHER}$ – Air, water and other transport required to ship good *i* from region *r* to *s*.

We develop a production function generating composite international transport good with three inputs exported by different regions to the global transport sector. Here we use three inputs as opposed to the two-input model we developed in the previous section for estimation of modal substitution elasticities. In the GTAP model the margins of international trade and transport are modeled explicitly. Transport services are exported by each region to the global transport sector that produces international transport good in the model. Whenever the source country exports a commodity to the country of destination, it is being combined with composite international transport good in fixed proportions, thereby generating the CIF price of the commodity in the destination country.

The detailed derivation of the modal substitution module for the GTAP model is presented in Appendix A. We use expressions (44a) - (44c) from Appendix A to introduce the following expression in percent change form to the modified GTAP model:

$$qtmfsd_{m,i,r,s} = - atmfsd_{m,i,r,s} + qxs_{i,r,s} - ESUBTRANS_{i,r,s} *(pt_m - atmfsd_{m,i,r,s} - ptran_{i,r,s}) \quad (10)$$

where:

$qtmfsd_{m,i,r,s}$ - international usage of margin *m* to ship good *i* from region *r* to *s*;

$atmfsd_{m,i,r,s}$ - technical change in margin *m* shipping good *i* from region *r* to *s*;

$qxs_{i,r,s}$ - export sales of commodity *i* from region *r* to *s*;

$ESUBTRANS_{i,r,s}$ - elasticity of modal substitution to ship good *i* from region *r* to *s*;

pt_m - price of composite margins services;

$ptran_{i,r,s}$ - cost index for international transport shipping good *i* from region *r* to *s*.

We obtain the value of $ESUBTRANS_{i,r,s}$ by commodity, source and destination using the weighted transport cost share from the GTAP version 6 data base, where transportation costs reflect the cost of shipping good *i* from source *r* to destination *s* by each of the transport modes in the data base. It is necessary to mention an important limitation of the GTAP international transport modal shares, by commodity. These estimates are based on the modal shares for the United States. This is an important limitation which should be addressed in future work. Expression (10) replaces the existing equation of bilateral demand for transport services in the GTAP model. The latter considers the demand for transport services to be proportional to the quantity of transported goods ($qxs_{i,r,s}$). Both expressions incorporate input-augmenting route and commodity specific technical change, represented by variable $atmfsd_{m,i,r,s}$. With improvements in technology $atmfsd_{m,i,r,s}$ becomes positive and reduces the requirements of margins services for shipping commodity *i* from source *r* to destination *s*. While lessening the bilateral demand for transport services, the positive change in the technology also decreases the shipping costs, reflected by lower CIF prices. Finally, the relative price of transport is in negative relationship with the bilateral demand for transportation services.

Implications for global trade facilitation and modal choice

In this section we analyze the impact of global trade facilitation on modal choice in international trade. Trade facilitation refers to a range of activities aimed at improving trade capacities of different countries. Wilson et al. (2003) describe it as improving logistics at both customs and ports of entry and developing more efficient administration and procedures. Currently, institutions across the world, such as the World Bank, International Trade Center, and the European Commission, put more emphasis on trade facilitation, which can be characterized by their increased spending on such projects. Since the trade facilitation depends extensively on international transport, it becomes important to understand how the improvement in logistics will affect the modal choice in international trade.

For this purpose we construct a 'trade facilitation' scenario using the Logistics Performance Index developed by the World Bank, and measure the facilitation of trade as an improvement in LPI. Specifically, the changes in LPI index values between 2007 and 2012 are computed based on the estimates of Arvis et al. (2007) and Arvis et al. (2012).

Since there are 19 regions in the modified version of GTAP model, we compute weighted average LPIs for different country groups corresponding to each broad GTAP region. For this purpose we use total export and import shares available from the World Bank data base[2]. This approach allows having variation in exporting and importing region LPIs.

We then compute the changes in LPI, which affect the demand for each transport mode the following way. Equation (52) in Appendix B shows that the relationship between the change in composite LPI and factor productivity is positive. Thus, the improvement in LPI will increase the factor productivity of transport. The values and changes in LPI are summarized in Table 3.

[2] See World Development Indicators available at http://data.worldbank.org/data-catalog/world-development-indicators

Table 3. Levels and changes in LPI by region between 2007 and 2012

Region	Level				Percent Change	
	Export Region LPI, 2007	Import Region LPI, 2007	Export Region LPI, 2012	Import Region LPI, 2012	Export Region LPI	Import Region LPI
United States	3.84	3.84	3.93	3.93	2.34	2.34
European Union	3.85	3.83	3.83	3.82	-0.42	-0.40
Brazil	2.75	2.75	3.13	3.13	13.82	13.82
Canada	3.92	3.92	3.85	3.85	-1.79	-1.79
Japan	4.02	4.02	3.93	3.93	-2.24	-2.24
China and Hong Kong	3.62	3.63	3.78	3.79	4.57	4.52
India	3.07	3.07	3.08	3.08	0.33	0.33
Central and Caribbean Americas	2.82	2.81	3.01	2.99	6.47	6.46
South and Other Americas	2.82	2.81	2.87	2.88	1.76	2.60
East Asia	3.52	3.52	3.70	3.70	5.11	5.11
Malaysia and Indonesia	3.29	3.30	3.27	3.28	-0.65	-0.61
Rest of South East Asia	3.69	3.66	3.68	3.65	-0.48	-0.13
Rest of South Asia	2.54	2.53	2.80	2.80	10.19	10.49
Russia	2.37	2.37	2.58	2.58	8.86	8.86
Other East Europe	2.77	2.73	3.12	3.08	12.51	12.90
Rest of European Countries	3.93	3.95	3.75	3.76	-4.65	-4.82
Middle Eastern and North Africa	2.71	2.64	2.91	2.88	7.42	9.13
Sub Saharan Africa	2.98	2.91	3.15	3.06	5.88	5.03
Oceania countries	3.75	3.76	3.64	3.65	-2.80	-2.76

Next, from equations (41) to (43) in Appendix A, we see that the factor productivity is negatively related to the demand for aggregate transport good. Therefore, increasing factor productivity will reduce the overall transport demand, resulting in a reduction of modal usage. Also, depending on a country and product pair, the substitution between each transport mode and the aggregate transport good can have both positive and negative impact on modal choice.

Using the exogenous factor productivity changes we run the 'trade facilitation' simulation and summarize the results in Table 4.

Table 4. Change in transport output by region and mode, percent

Region	Other transport	Water transport	Air transport
United States	-0.05	-2.58	-0.52
European Union	-0.15	-9.01	0.40
Brazil	0.25	-8.08	-1.40
Canada	-0.22	-2.52	0.80
Japan	-0.02	-7.38	-0.58
China and Hong Kong	-0.74	-6.38	-2.50
India	-0.02	-1.66	-1.80
Central and Caribbean Americas	0.09	-2.53	0.17
South and Other Americas	-0.17	-7.09	-1.26
East Asia	-1.73	-11.83	-3.57
Malaysia and Indonesia	-0.04	-9.51	-0.65
Rest of South East Asia	-0.58	-8.48	-1.30
Rest of South Asia	0.82	-0.44	-1.81
Russia	-0.44	-5.91	-2.51
Other East Europe	-1.40	-5.30	-2.87
Rest of European Countries	-11.52	-16.26	-62.53
Middle Eastern and North Africa	-0.28	-7.31	-1.02
Sub Saharan Africa	0.13	-4.72	-0.63
Oceania countries	0.17	-2.74	0.56
World	-0.34	-7.07	-1.51

It is interesting that the reduction in air transport output in Rest of European Countries is the largest across all regions. As previously indicated, larger composite LPI generates a bias towards air transport (equations (5) and (6)). Moreover, some countries produce high value products and require better logistics for fast shipping of such goods via air transport. Finally, the demand for air transport may increase due to growing demand for 'just in time' delivery of intermediate products. Therefore, in some regions, such as the European Union, Canada, Central and Caribbean Americas and Oceania countries, growing LPI will increase the use of air transport. In other countries, such as the United States, Brazil, Japan, etc., the improvement in logistics reduces the demand for air transportation, but the reduction in water transport is more significant, resulting in a relatively higher use of air transport. Equivalently, decreasing LPI may reduce the demand for air transportation, which is observed in Rest of European Countries. In these countries, the composite LPI experiences the largest reduction across all regions, declining by 10.2% between 2007 and 2012. The latter results in a 62.5% reduction of air transport demand in Rest of European Countries.

There are also changes in the output, consumption and trade balance of transport air services due to changes in global logistics performance (Table 5).

Table 5. Change in air transport output, consumption and trade

Regions	Change in air transport				
	Production, percent	Consumption, percent	Exports, percent	Imports, percent	Trade balance, $US million
United States	-0.5	0.1	-4.0	-1.3	-1,146
European Union	0.4	-0.3	0.1	-1.3	31
Brazil	-1.4	1.7	-10.9	1.4	-69
Canada	0.8	-0.2	2.9	-1.7	160
Japan	-0.6	-0.4	-3.1	-1.8	-206
China and Hong Kong	-2.5	1.2	-7.1	1.8	-598
India	-1.8	0.2	-9.5	-0.4	-63
Central and Caribbean Americas	0.2	0.9	-2.4	0.9	-124
South and Other Americas	-1.3	0.4	-5.6	0.5	-184
East Asia	-3.6	1.6	-7.3	0.4	-526
Malaysia and Indonesia	-0.7	-0.3	-1.3	-0.7	-30
Rest of South East Asia	-1.3	-0.2	-2.7	-0.9	-153
Rest of South Asia	-1.8	2.9	-5.5	1.3	-64
Russia	-2.5	1.3	-8.7	2.6	-227
Other East Europe	-2.9	3.6	-8.9	2.8	-228
Rest of European Countries	-62.5	-16.7	-93.0	14.3	-2,933
Middle Eastern and North Africa	-1.0	1.4	-4.1	0.8	-230
Sub Saharan Africa	-0.6	1.6	-2.7	0.6	-76
Oceania countries	0.6	-0.8	1.8	-1.8	99
Total	-1.5	-1.5	-4.4	-0.5	-6,566

The decline in air transport services output negatively affects its consumption, reducing the output of global air transport by 1.5%. We find that the increase in the European, Canadian, and Oceania air transport services output increases their exports, and, accordingly, their balance of trade. Changes in the production, consumption, and trade for maritime and other transport services are shown in Tables B.1 and B.2 in Appendix B. The trade balance of transport services is declining in regions with negative changes in both production and consumption, while it is increasing in others characterized by growing output levels. Also, the world trade balance for all sectors combined is equal to zero. The changes in bilateral exports and imports of tradable commodities are shown in Table B.3 in Appendix B, which shows that improved logistics significantly increases the overall trade volumes across different routes.

Conclusions

In this study we analyze the impact of improved logistics on transport sectors, in particular modal choice and world trade. For this purpose we estimate the elasticities of modal substitution for land-air and water-air transport pairs, and then modify the GTAP general equilibrium model by incorporating modal substitution. In estimating the modal substitution elasticities we maintain the variation across HS 6 level commodities and origin-destination pairs, and hence restrict these elasticities to be equal within each broad GTAP sector. Such approach enables us to preserve the variation of freight and insurance values and quantities within each GTAP sector and more accurately estimate the elasticities of modal substitution. We apply the weighted transport cost share from the GTAP version 6 data base to the estimated elasticities of modal substitution for land-air and water-air transport pairs and obtain the value of modal substitution elasticities by commodity, source and destination, and then incorporate these into the GTAP model.

Since the quality of logistics infrastructure varies across countries, we assume that this index will affect modal choice in international trade. Thus, we substitute the distribution parameters with the Logistics Performance Index developed by the World Bank, which allows us to control for both exporter and importer effects. We find that higher logistics performance increases the demand for international air transport.

Under global trade facilitation we anticipate a bias towards air transport. We find that improvement in logistics will reduce the overall cost of transport and amount of services required to transport a given product along a given route by a given mode. Also, the reduction in modal cost of transport will result in modal substitution. In some regions improvement in logistics increases the use of air transport. In other countries, trade facilitation measures reduce the demand for air and maritime transport modes, having a significant negative impact on water transportation, and, therefore, resulting in a relatively increased demand for air transport. Finally, improvement in logistics results in growing trade between different countries.

For future research it will be interesting to analyze the modal choice impacts of improved logistics in countries that have below average LPI and improve their logistics to the world average, given the dynamic changes in the logistics performance across different regions.

References

Arvis, Jean-François, Monica Alina Mustra, John Panzer, Lauri Ojala and Tapio Naula. 2007. Connecting to Compete - Trade Logistics in the Global Economy - The Logistics Performance Index and its Indicators. International Trade Department, The World Bank, Washington DC.

Arvis, Jean-François, Monica Alina Mustra, Lauri Ojala, Ben Shepherd and Daniel Saslavsky. 2012. Connecting to Compete 2012 - Trade Logistics in the Global Economy - The Logistics Performance Index and its Indicators. International Trade Department, The World Bank, Washington DC.

Avetisyan, M., N. Heatwole, A. Rose and B. Roberts. 2015. Competitiveness and Macroeconomic Impacts of Reduced Wait Times at U.S. Land Freight Border Crossings. *Transportation Research Part A: Policy and Practice* 78: 84-101.

Bourdet, Y. and M. Persson. 2014. Expanding and diversifying south Mediterranean Exports through Trade Facilitation. *Development policy review* 32(6): 675-699.

Claro, Sebastian. 2002. A Cross-Country Estimation of the Elasticity of Substitution between Labor and Capital in Manufacturing Industries. Instituto de Economia, Universidad Catolica de Chile, Santiago, Chile.

Cristea, A., D. Hummels, L. Puzzello, and M. Avetisyan. 2013. Trade and the Greenhouse Gas Emissions from International Freight Transport. *Journal of Environmental Economics and Management* 65(1): 153-173

Dennis, A. 2010. Global Economic Crisis and Trade: the role of trade facilitation. *Applied Economic Letters* 17: 1753-1757.

Felipe, J. and V. Kumar. 2012. The Role of Trade Facilitation in Central Asia. *Eastern European Economics* 50(4): 5-20.

Hertel, Thomas. 1997. *Global Trade Analysis: Modeling and Applications*. Cambridge: Cambridge University Press.

Hoekman, B. and A. Nicita. 2010. Assessing the Doha Round: Market access, transactions costs and aid for trade facilitation. *The Journal of International Trade and Economic Development* 19(1): 65-75.

Hummels, D., V. Lugovskyy and A. Skiba. 2009. The trade reducing effects of market power in international shipping. *Journal of Development Economics* 89(1): 84-97.

Marti, L., R. Puertas and L. Garcia. 2014. Relevance of trade facilitation in emerging countries' exports. *The Journal of International Trade & Economic development* 23(2): 202-222.

Neufeld, N. 2014. Trade facilitation Provisions in Regional Trade Agreement: Traits and Trends. *Journal of International Commerce, Economic and Policy* 5(2): 1-28.

Robert, C.F. and M. Hong. 2014. Trade Facilitation and the extensive margin of exports. *The Japanese Economic Review* 65(2): 158-177.

Wilson, J. S., C. L. Mann and T. Otsuki. 2003. "Trade facilitation and economic development: Measuring the impact". Technical report, World Bank Policy Research Working Paper 2988.

Zaki, C. 2014. An empirical assessment of the trade facilitation intuitive: economic evidence and global economic effects. *World Trade Review* 13(1): 103-130.

Appendix A

Model for estimating elasticities of modal substitution

Land-Air substitution

We define a CES production function for an aggregate transportation input, which is a mix of air and land transport, produced at a cost that is a weighted average of air and land shipping. In the following producer cost minimization problem we minimize transportation costs subject to aggregate transport production:

$$\min\ P^A_{i,r,s} * A_{i,r,s} + P^L_{i,r,s} * L_{i,r,s} \tag{1}$$

s.t. $Q^{TRANSPORT}_{i,r,s} = F^l * [\alpha * A^{-\rho}_{i,r,s} + \beta * L^{-\rho}_{i,r,s}]^{-\frac{1}{\rho}}$, where $\rho = \dfrac{1-\sigma^l_i}{\sigma^l_i}$

Or:

$$Z = P^A_{i,r,s} * A_{i,r,s} + P^L_{i,r,s} * L_{i,r,s} - \lambda * (F^l * [\alpha * A^{-\rho}_{i,r,s} + \beta * L^{-\rho}_{i,r,s}]^{-\frac{1}{\rho}} - Q^{TRANSPORT}_{i,r,s}) \tag{2}$$

where,

$Q^{TRANSPORT}_{i,r,s}$ – Total transportation required to ship good *i* from region *r* to *s*;

F^l - Factor productivity;

α, β – Distribution parameters;

σ^l_i – Elasticity of substitution between land and air transport modes for good *i*;

$A_{i,r,s}$ – Air transport required to ship good *i* from region *r* to *s*;

$L_{i,r,s}$ – Land transport required to ship good *i* from region *r* to *s*;

$P^A_{i,r,s}, P^L_{i,r,s}$ – Prices of air and land transport to ship good *i* from region *r* to *s*.

For simplicity we temporarily omit the index *(i,r,s)* from all expressions. We then find the first order conditions:

$$P_A + \frac{\lambda}{\rho} * F * [\alpha * A^{-\rho} + \beta * L^{-\rho}]^{-\frac{1}{\rho}-1} * \alpha * (-\rho) * A^{-\rho-1} = 0 \tag{3}$$

$$P_L + \frac{\lambda}{\rho} * F * [\alpha * A^{-\rho} + \beta * L^{-\rho}]^{-\frac{1}{\rho}-1} * \beta * (-\rho) * L^{-\rho-1} = 0 \quad (4)$$

Then:

$$P_A = \frac{\lambda}{\rho} * F * [\alpha * A^{-\rho} + \beta * L^{-\rho}]^{-\frac{1}{\rho}-1} * \alpha * \rho * A^{-\rho-1} \quad (5)$$

$$P_L = \frac{\lambda}{\rho} * F * [\alpha * A^{-\rho} + \beta * L^{-\rho}]^{-\frac{1}{\rho}-1} * \beta * \rho * L^{-\rho-1} \quad (6)$$

Next, we divide both sides by each other:

$$\frac{P_A}{P_L} = \frac{\frac{\lambda}{\rho} * F * [\alpha * A^{-\rho} + \beta * L^{-\rho}]^{-\frac{1}{\rho}-1} * \alpha * \rho * A^{-\rho-1}}{\frac{\lambda}{\rho} * F * [\alpha * A^{-\rho} + \beta * L^{-\rho}]^{-\frac{1}{\rho}-1} * \beta * \rho * L^{-\rho-1}} \quad (7)$$

Then we will have:

$$\frac{P_A}{P_L} = \frac{\alpha * A^{-\rho-1}}{\beta * L^{-\rho-1}} \Rightarrow \frac{P_A}{P_L} = \frac{\alpha}{\beta} * \left(\frac{A}{L}\right)^{-\rho-1} \quad (8)$$

Since $\rho = \frac{1-\sigma_i^l}{\sigma_i^l}$ then we can write $-\rho - 1 = \frac{\sigma_i^l - 1}{\sigma_i^l} - 1 = -\frac{1}{\sigma_i^l}$

So we will have:

$$\frac{P_A}{P_L} = \frac{\alpha}{\beta} * \left(\frac{A}{L}\right)^{-\frac{1}{\varepsilon_i}} \Rightarrow \frac{P_A}{P_L} = \frac{\alpha}{\beta} * \left(\frac{L}{A}\right)^{\frac{1}{\varepsilon_i}} \quad (9)$$

Log differentiating and converting to percent changes (lower case shows the percent change in the associated upper case variable), we get the following equation:

$$\log\left[\frac{\alpha}{\beta} * \left(\frac{L}{A}\right)^{\frac{1}{\varepsilon_i}}\right] = \log\left[\frac{P_A}{P_L}\right] \quad (10)$$

$$d\left[\log\alpha - \log\beta + \frac{1}{\sigma_i^l} * (\log L - \log A)\right] = d\left[\log P_A - \log P_L\right] \quad (11)$$

$$\frac{1}{\sigma_i^l} * \left(\frac{dL}{L} - \frac{dA}{A}\right) = \frac{dP_A}{P_A} - \frac{dP_L}{P_L} \qquad (12)$$

$$l - a = \sigma_i^l (p_A - p_L) \qquad (13a)$$

By introducing index *(i,r,s)* we will have:

$$l_{i,r,s} - a_{i,r,s} = \sigma_i^l (p_{i,r,s}^A - p_{i,r,s}^L) \qquad (13b)$$

$$l_{i,r,s} = a_{i,r,s} - \sigma_i^l (p_{i,r,s}^L - p_{i,r,s}^A) \qquad (13c)$$

where,

$a_{i,r,s}$ – Percent change in air transport use to ship good *i* from region *r* to *s*.

$l_{i,r,s}$ – Percent change in land transport use to ship good *i* from region *r* to *s*.

$p_{i,r,s}^A$ – Percent change in air transport price to ship good *i* from region *r* to *s*.

$p_{i,r,s}^L$ – Percent change in land transport price to ship good *i* from region *r* to *s*.

Water-Air substitution

Using the same approach we derive similar equation for water and air transport substitution:

$$w_{i,r,s} = a_{i,r,s} - \sigma_i^{nl} (p_{i,r,s}^W - p_{i,r,s}^A) \qquad (14)$$

where,

$w_{i,r,s}$ – Percent change in water transport use to ship good *i* from region *r* to *s*.

$p_{i,r,s}^W$ – Percent change in water transport price to ship good *i* from region *r* to *s*.

Modal substitution model for GTAP

In the following producer cost minimization problem we minimize transportation costs subject to aggregate transport production:

$$\min P_{i,r,s}^{AIR} * Q_{i,r,s}^{AIR} + P_{i,r,s}^{WATER} * Q_{i,r,s}^{WATER} + P_{i,r,s}^{OTHER} * Q_{i,r,s}^{OTHER} \qquad (15)$$

s.t.

$$Q_{i,r,s}^{TRANSPORT} = F * [\alpha * Q_{i,r,s}^{AIR^{-\rho}} + \beta * Q_{i,r,s}^{WATER^{-\rho}} + \gamma * Q_{i,r,s}^{OTHER^{-\rho}}]^{-\frac{1}{\rho}}$$

where: $\rho = \dfrac{1-\sigma_i}{\sigma_i}$

$Q_{i,r,s}^{AIR}$ – Air transport required to ship good *i* from region *r* to *s*;

$Q_{i,r,s}^{WATER}$ – Water transport required to ship good *i* from region *r* to *s*;

$Q_{i,r,s}^{OTHER}$ – Other transport required to ship good *i* from region *r* to *s*.

$P_{i,r,s}^{AIR}$ – Price of air transport required to ship good *i* from region *r* to *s*;

$P_{i,r,s}^{WATER}$ – Price of water transport required to ship good *i* from region *r* to *s*;

$P_{i,r,s}^{OTHER}$ – Price of other transport required to ship good *i* from region *r* to *s*;

$P_{i,r,s}^{TRANSPORT}$ – Flow-specific modal average cost of transport to ship good *i* from region *r* to *s*.

So, we will have:

$$Z = P_{i,r,s}^{AIR} * Q_{i,r,s}^{AIR} + P_{i,r,s}^{WATER} * Q_{i,r,s}^{WATER} + P_{i,r,s}^{OTHER} * Q_{i,r,s}^{OTHER} \qquad (16)$$
$$-\lambda * \left[F * [\alpha * Q_{i,r,s}^{AIR^{-\rho}} + \beta * Q_{i,r,s}^{WATER^{-\rho}} + \gamma * Q_{i,r,s}^{OTHER^{-\rho}}]^{-\frac{1}{\rho}} - Q_{i,r,s}^{TRANSPORT} \right]$$

As before, for the time being we omit the index *(i,r,s)* from all expressions. We then find the first order conditions:

$$P_{AIR} + \frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \alpha * (-\rho) * Q_{AIR}{}^{-\rho-1} = 0 \quad (17)$$

$$P_{WATER} + \frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \beta * (-\rho) * Q_{WATER}{}^{-\rho-1} = 0 \quad (18)$$

$$P_{OTHER} + \frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \gamma * (-\rho) * Q_{OTHER}{}^{-\rho-1} = 0 \quad (19)$$

Or:

$$P_{AIR} = \frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \alpha * \rho * Q_{AIR}{}^{-\rho-1} \quad (20)$$

$$P_{WATER} = \frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \beta * \rho * Q_{WATER}{}^{-\rho-1} \quad (21)$$

$$P_{OTHER} = \frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \gamma * \rho * Q_{OTHER}{}^{-\rho-1} \quad (22)$$

Next, we divide both sides by each other:

$$\frac{P_{AIR}}{P_{WATER}} = \frac{\frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \alpha * \rho * Q_{AIR}{}^{-\rho-1}}{\frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \beta * \rho * Q_{WATER}{}^{-\rho-1}} \quad (23)$$

$$\frac{P_{AIR}}{P_{OTHER}} = \frac{\frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \alpha * \rho * Q_{AIR}{}^{-\rho-1}}{\frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \gamma * \rho * Q_{OTHER}{}^{-\rho-1}} \quad (24)$$

$$\frac{P_{WATER}}{P_{OTHER}} = \frac{\frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \beta * \rho * Q_{WATER}{}^{-\rho-1}}{\frac{\lambda}{\rho} * F * [\alpha * Q_{AIR}{}^{-\rho} + \beta * Q_{WATER}{}^{-\rho} + \gamma * Q_{OTHER}{}^{-\rho}]^{-\frac{1}{\rho}-1} * \gamma * \rho * Q_{OTHER}{}^{-\rho-1}} \quad (25)$$

Then we will have:

$$\frac{P_{AIR}}{P_{WATER}} = \frac{\alpha * Q_{AIR}^{-\rho-1}}{\beta * Q_{WATER}^{-\rho-1}} \Rightarrow \frac{Q_{AIR}}{Q_{WATER}} = \left[\frac{\beta * P_{AIR}}{\alpha * P_{WATER}}\right]^{\frac{1}{-1-\rho}} \Rightarrow Q_{WATER} = Q_{AIR}\left[\frac{\beta * P_{AIR}}{\alpha * P_{WATER}}\right]^{\frac{1}{1+\rho}} \quad (26)$$

$$\frac{P_{AIR}}{P_{OTHER}} = \frac{\alpha * Q_{AIR}^{-\rho-1}}{\gamma * Q_{OTHER}^{-\rho-1}} \Rightarrow \frac{Q_{AIR}}{Q_{OTHER}} = \left[\frac{\gamma * P_{AIR}}{\alpha * P_{OTHER}}\right]^{\frac{1}{-1-\rho}} \Rightarrow Q_{OTHER} = Q_{AIR}\left[\frac{\gamma * P_{AIR}}{\alpha * P_{OTHER}}\right]^{\frac{1}{1+\rho}} \quad (27)$$

$$\frac{P_{WATER}}{P_{OTHER}} = \frac{\beta * Q_{WATER}^{-\rho-1}}{\gamma * Q_{OTHER}^{-\rho-1}} \Rightarrow \frac{Q_{WATER}}{Q_{OTHER}} = \left[\frac{\gamma * P_{WATER}}{\beta * P_{OTHER}}\right]^{\frac{1}{-1-\rho}} \Rightarrow Q_{OTHER} = Q_{WATER}\left[\frac{\gamma * P_{WATER}}{\beta * P_{OTHER}}\right]^{\frac{1}{1+\rho}} \quad (28)$$

By substituting these equations back into the CES production function, we get:

$$\left(\frac{Q_{TRANSPORT}}{F}\right)^{-\rho} = \alpha * Q_{AIR}^{-\rho} + \beta * Q_{WATER}^{-\rho} + \gamma * Q_{OTHER}^{-\rho} = \alpha * Q_{AIR}^{-\rho} + \beta * Q_{AIR}^{-\rho}\left[\frac{\beta * P_{AIR}}{\alpha * P_{WATER}}\right]^{-\frac{\rho}{1+\rho}} + \gamma * Q_{AIR}^{-\rho}\left[\frac{\gamma * P_{AIR}}{\alpha * P_{OTHER}}\right]^{-\frac{\rho}{1+\rho}} \quad (29)$$

Or:

$$\left(\frac{Q_{TRANSPORT}}{F}\right)^{-\rho} = Q_{AIR}^{-\rho} * \left[\frac{P_{AIR}}{\alpha}\right]^{-\frac{\rho}{1+\rho}}\left(\alpha^{1-\frac{\rho}{1+\rho}} P_{AIR}^{\frac{\rho}{1+\rho}} + \beta^{1-\frac{\rho}{1+\rho}} P_{WATER}^{\frac{\rho}{1+\rho}} + \gamma^{1-\frac{\rho}{1+\rho}} P_{OTHER}^{\frac{\rho}{1+\rho}}\right) =$$
$$= Q_{AIR}^{-\rho} * \left[\frac{P_{AIR}}{\alpha}\right]^{-\frac{\rho}{1+\rho}}\left(\alpha^{\frac{1}{1+\rho}} P_{AIR}^{\frac{\rho}{1+\rho}} + \beta^{\frac{1}{1+\rho}} P_{WATER}^{\frac{\rho}{1+\rho}} + \gamma^{\frac{1}{1+\rho}} P_{OTHER}^{\frac{\rho}{1+\rho}}\right) \quad (30)$$

Then, we solve for Q_{AIR}:

$$Q_{AIR} = \frac{Q_{TRANSPORT}}{F} * \left[\frac{\alpha}{P_{AIR}}\right]^{\frac{1}{1+\rho}}\left(\alpha^{\frac{1}{1+\rho}} P_{AIR}^{\frac{\rho}{1+\rho}} + \beta^{\frac{1}{1+\rho}} P_{WATER}^{\frac{\rho}{1+\rho}} + \gamma^{\frac{1}{1+\rho}} P_{OTHER}^{\frac{\rho}{1+\rho}}\right)^{\frac{1}{\rho}} \quad (31)$$

$$Q_{WATER} = \frac{Q_{TRANSPORT}}{F} * \left[\frac{\beta}{P_{WATER}}\right]^{\frac{1}{1+\rho}}\left(\alpha^{\frac{1}{1+\rho}} P_{AIR}^{\frac{\rho}{1+\rho}} + \beta^{\frac{1}{1+\rho}} P_{WATER}^{\frac{\rho}{1+\rho}} + \gamma^{\frac{1}{1+\rho}} P_{OTHER}^{\frac{\rho}{1+\rho}}\right)^{\frac{1}{\rho}} \quad (32)$$

$$Q_{OTHER} = \frac{Q_{TRANSPORT}}{F} * \left[\frac{\gamma}{P_{OTHER}}\right]^{\frac{1}{1+\rho}}\left(\alpha^{\frac{1}{1+\rho}} P_{AIR}^{\frac{\rho}{1+\rho}} + \beta^{\frac{1}{1+\rho}} P_{WATER}^{\frac{\rho}{1+\rho}} + \gamma^{\frac{1}{1+\rho}} P_{OTHER}^{\frac{\rho}{1+\rho}}\right)^{\frac{1}{\rho}} \quad (33)$$

Next, we introduce the aggregate transport cost $P_{TRANSPORT}$:

$$P_{TRANSPORT} = \frac{C(Q_{TRANSPORT}, P_{AIR}, P_{WATER}, P_{OTHER})}{Q_{TRANSPORT}} =$$

$$\frac{P_{AIR} * Q_{AIR} + P_{WATER} * Q_{WATER} + P_{OTHER} * Q_{OTHER}}{Q_{TRANSPORT}} =$$

$$= \frac{1}{F} * \left(\alpha^{\frac{1}{1+\rho}} P_{AIR}{}^{\frac{\rho}{1+\rho}} + \beta^{\frac{1}{1+\rho}} P_{WATER}{}^{\frac{\rho}{1+\rho}} + \gamma^{\frac{1}{1+\rho}} P_{OTHER}{}^{\frac{\rho}{1+\rho}} \right)^{\frac{1}{\rho}} \tag{34}$$

$$* \left[\alpha^{\frac{1}{1+\rho}} P_{AIR}{}^{\frac{\rho}{1+\rho}} + \beta^{\frac{1}{1+\rho}} P_{WATER}{}^{\frac{\rho}{1+\rho}} + \gamma^{\frac{1}{1+\rho}} P_{OTHER}{}^{\frac{\rho}{1+\rho}} \right] =$$

$$= \frac{1}{F} * \left(\alpha^{\frac{1}{1+\rho}} P_{AIR}{}^{\frac{\rho}{1+\rho}} + \beta^{\frac{1}{1+\rho}} P_{WATER}{}^{\frac{\rho}{1+\rho}} + \gamma^{\frac{1}{1+\rho}} P_{OTHER}{}^{\frac{\rho}{1+\rho}} \right)^{1+\frac{1}{\rho}}$$

Therefore:

$$Q_{AIR} = \frac{Q_{TRANSPORT}}{F} * \left[\frac{\alpha}{P_{AIR}} \right]^{\frac{1}{1+\rho}} \left[F * P_{TRANSPORT} \right]^{\frac{1}{1+\rho}} \tag{35}$$

Since $\rho = \frac{1-\sigma_i}{\sigma_i}$ then we can write $\rho + 1 = \frac{1-\sigma_i}{\sigma_i} + 1 = \frac{1}{\sigma_i}$. Then:

$$Q_{AIR} = Q_{TRANSPORT} * \left[\frac{\alpha * P_{TRANSPORT}}{P_{AIR}} \right]^{\frac{1}{1+\rho}} * F^{-\frac{\rho}{1+\rho}} = Q_{TRANSPORT} * \left[\frac{\alpha * P_{TRANSPORT}}{P_{AIR}} \right]^{\sigma_i} * F^{\sigma_i - 1} \tag{36}$$

Similarly, we can write:

$$Q_{WATER} = Q_{TRANSPORT} * \left[\frac{\beta * P_{TRANSPORT}}{P_{WATER}} \right]^{\frac{1}{1+\rho}} * F^{-\frac{\rho}{1+\rho}} = Q_{TRANSPORT} * \left[\frac{\beta * P_{TRANSPORT}}{P_{WATER}} \right]^{\sigma_i} * F^{\sigma_i - 1} \tag{37}$$

$$Q_{OTHER} = Q_{TRANSPORT} * \left[\frac{\gamma * P_{TRANSPORT}}{P_{OTHER}} \right]^{\frac{1}{1+\rho}} * F^{-\frac{\rho}{1+\rho}} = Q_{TRANSPORT} * \left[\frac{\gamma * P_{TRANSPORT}}{P_{OTHER}} \right]^{\sigma_i} * F^{\sigma_i - 1} \tag{38}$$

Again, log differentiating and converting to percent changes (lower case shows the percent change in the associated upper case variable), we get the following equation:

$$\log Q_{AIR} = \log Q_{TRANSPORT} + \sigma_i (\log \alpha + \log P_{TRANSPORT} - \log P_{AIR}) + (\sigma_i - 1) \log F \quad (39)$$

$$d[\log Q_{AIR}] = d[\log Q_{TRANSPORT} + \sigma_i (\log \alpha + \log P_{TRANSPORT} - \log P_{AIR}) + (\sigma_i - 1) \log F] \quad (40)$$

$$q_{AIR} = q_{TRANSPORT} + \sigma_i (p_{TRANSPORT} - p_{AIR}) + (\sigma_i - 1) f \quad (41)$$

Applying similar approach, we find that:

$$q_{WATER} = q_{TRANSPORT} + \sigma_i (p_{TRANSPORT} - p_{WATER}) + (\sigma_i - 1) f \quad (42)$$

$$q_{OTHER} = q_{TRANSPORT} + \sigma_i (p_{TRANSPORT} - p_{OTHER}) + (\sigma_i - 1) f \quad (43)$$

Or:

$$q_{AIR} = -f + q_{TRANSPORT} - \sigma_i (p_{AIR} - f - p_{TRANSPORT}) \quad (44a)$$

$$q_{WATER} = -f + q_{TRANSPORT} - \sigma_i (p_{WATER} - f - p_{TRANSPORT}) \quad (44b)$$

$$q_{OTHER} = -f + q_{TRANSPORT} - \sigma_i (p_{OTHER} - f - p_{TRANSPORT}) \quad (44c)$$

In expressions (44a) – (44b) the value of σ_i is obtained by applying the weighted transport cost share from the GTAP data base in shipping good *i* from source *r* to destination *s*. As a result, σ_i varies also by shipping route, and therefore is represented as $\sigma_{i,r,s}$.

Appendix B

Impact of changes in LPI on factor productivity

We estimate the impact of LPI improvement on factor productivity using equations (5) and (7) from the section estimating elasticities of modal substitution. Specifically, we derive equation (45) using (5) and (7):

$$-\sigma_i^l * \log\frac{\alpha}{\beta} = k_{0,i}^l - k_{1,i}^l * \log LPI_r * LPI_s \quad (45)$$

$$\left(\frac{\alpha}{\beta}\right)^{-\sigma_i^l} = e^{k_{0,i}^l - k_{1,i}^l * \log LPI_r * LPI_s}$$

$$\frac{\alpha}{\beta} = e^{-\frac{1}{\sigma_i^l}\left(k_{0,i}^l - k_{1,i}^l * \log LPI_r * LPI_s\right)}$$

Thus:

$$\alpha = \beta * e^{-\frac{1}{\sigma_i^l}\left(k_{0,i}^l - k_{1,i}^l * \log LPI_r * LPI_s\right)} \quad (46)$$

Using equation (36) we can write:

$$Q_{AIR} = Q_{TRANSPORT} * \left[\frac{\alpha * c_{TRANSPORT}}{P_{AIR}}\right]^{\sigma_i} * F^{\sigma_i - 1} \quad (47)$$

$$= Q_{TRANSPORT} * \left[\frac{\beta * e^{-\frac{1}{\sigma_i^l}\left(k_{0,i}^l - k_{1,i}^l * \log LPI_r * LPI_s\right)} * c_{TRANSPORT}}{P_{AIR}}\right]^{\sigma_i} * F^{\sigma_i - 1}$$

Log differentiating and converting to percent changes (lower case shows the percent change in the associated upper case variable), we get the following equations:

$$\log Q_{AIR} = \log Q_{TRANSPORT} + \sigma_i\left(-\frac{1}{\sigma_i^l}(k_{0,i}^l - k_{1,i}^l * \log LPI_r * LPI_s) + \log\beta + \log c_{TRANSPORT} - \log P_{AIR}\right) + (\sigma_i - 1)\log F \quad (48)$$

$$d[\log Q_{AIR}] = d\left[\log Q_{TRANSPORT} + \sigma_i\left(-\frac{1}{\sigma_i^l}(k_{0,i}^l - k_{1,i}^l * \log LPI_r * LPI_s) + \log\beta + \log c_{TRANSPORT} - \log P_{AIR}\right)\right] + d[(\sigma_i - 1)\log F] \quad (49)$$

$$q_{AIR} = q_{TRANSPORT} + \sigma_i \frac{k_{1,i}^l}{\sigma_i^l}(lpi_r lpi_s) + \sigma_i (p_{TRANSPORT} - p_{AIR}) + (\sigma_i - 1) f \quad (50)$$

$$f = \frac{q_{AIR} - q_{TRANSPORT} - \sigma_i (p_{TRANSPORT} - p_{AIR})}{\sigma_i - 1} - \frac{\sigma_i * k_{1,i}^l}{\sigma_i^l * (\sigma_i - 1)}(lpi_r lpi_s) \quad (51)$$

Equation (51) shows that the percent change in factor productivity for different modes of transport is positively related to the percent change in the product of exporting and importing country LPIs. Since the change in factor productivity is zero with no change in LPI (for all transport modes), then a change in the product of exporting and importing country LPIs will induce a similar change in factor productivity adjusted by the ratio of substitution elasticities:

$$f = \underbrace{\frac{q_{AIR} - q_{TRANSPORT} - \sigma_i (p_{TRANSPORT} - p_{AIR})}{\sigma_i - 1}}_{0} - \underbrace{\frac{\sigma_i * k_{1,i}^l}{\sigma_i^l * (\sigma_i - 1)}}_{ratio \geq 0}(lpi_r lpi_s) \quad (52)$$

$$where: k_{1,i}^l < 0, \quad \sigma_i^l > 0, \quad \sigma_i > 1$$

Tables

Table B.1. Change in water transport output, consumption and trade

Regions	Change in water transport				
	Production, percent	Consumption, percent	Exports, percent	Imports, percent	Trade balance, $US million
United States	-2.6	0.1	-12.2	-0.6	-1,118
European Union	-9.0	-0.1	-11.0	-4.4	-8,875
Brazil	-8.1	1.8	-12.8	1.1	-170
Canada	-2.5	-0.2	-8.2	-1.0	-180
Japan	-7.4	-0.1	-12.9	-7.7	-3,066
China and Hong Kong	-6.4	1.4	-13.6	0.1	-1,293
India	-1.7	0.2	-11.3	-0.5	-180
Central and Caribbean Americas	-2.5	0.9	-9.3	0.8	-200
South and Other Americas	-7.1	0.4	-12.4	-1.6	-384
East Asia	-11.8	1.6	-13.1	-10.8	-1,036
Malaysia and Indonesia	-9.5	-0.3	-12.7	-1.1	-414
Rest of South East Asia	-8.5	-0.2	-12.3	-3.1	-587
Rest of South Asia	-0.4	2.7	-15.1	4.0	-83
Russia	-5.9	1.5	-14.3	2.7	-289
Other East Europe	-5.3	3.5	-14.7	3.3	-475
Rest of European Countries	-16.3	-7.2	-17.8	-9.5	-1,588
Middle Eastern and North Africa	-7.3	1.4	-14.4	-0.7	-1,033
Sub Saharan Africa	-4.7	1.6	-10.1	0.8	-149
Oceania countries	-2.7	-0.6	-8.7	-2.8	-127
Total	-7.1	-7.1	-12.3	-4.5	-21,247

Table B.2. Change in other transport output, consumption and trade

Regions	Change in other transport				
	Production, percent	Consumption, percent	Exports, percent	Imports, percent	Trade balance, $US million
United States	-0.1	0.1	-2.2	-1.2	-396
European Union	-0.2	0.0	-1.5	-2.4	-640
Brazil	0.2	1.6	-6.4	2.2	-50
Canada	-0.2	-0.1	-2.0	-1.6	-167
Japan	0.0	-0.1	1.5	-3.2	230
China and Hong Kong	-0.7	1.1	-7.1	1.6	-784
India	0.0	0.2	-2.9	-0.6	-59
Central and Caribbean Americas	0.1	0.8	-4.2	1.1	-288
South and Other Americas	-0.2	0.3	-4.0	-0.1	-118
East Asia	-1.7	1.0	-7.6	-4.8	-352
Malaysia and Indonesia	0.0	-0.2	0.0	-2.0	17
Rest of South East Asia	-0.6	-0.1	-1.9	-3.5	-56
Rest of South Asia	0.8	2.6	-10.2	3.7	-65
Russia	-0.4	1.3	-8.0	2.9	-259
Other East Europe	-1.4	3.2	-10.1	2.7	-1,055
Rest of European Countries	-11.5	-10.2	-24.4	-4.8	-723
Middle Eastern and North Africa	-0.3	1.2	-4.8	0.0	-371
Sub Saharan Africa	0.1	1.6	-3.2	0.8	-107
Oceania countries	0.2	-0.6	0.2	-2.2	33
Total	-0.3	-0.3	1.3	-1.7	-5,210

Table B.3. Change in bilateral trade flows in tradable merchandise, US$ million

Regions	United States	European Union	Brazil	Canada	Japan	China and Hong Kong	India	Central and Caribbean Americas	South and Other Americas	East Asia	Malaysia and Indonesia	Rest of South East Asia	Rest of South Asia	Russia	Other East Europe	Rest of European Countries	Middle Eastern and North Africa	Sub Saharan Africa	Oceania countries	Total
United States	0	1,143	1,863	-185	-66	1,774	143	3,404	897	2,025	200	849	114	-149	-15	465	189	232	345	13,231
European Union	4,787	-18,984	2,279	-749	-1,290	2,887	78	1,696	279	1,765	70	140	296	2,448	7,254	-26,839	6,113	1,492	-905	-17,183
Brazil	1,357	417	0	44	61	20	-23	315	1,403	71	-5	-21	-6	-51	-2	-9	-90	117	15	3,612
Canada	-603	-740	146	0	-925	225	-25	110	7	143	-39	-27	19	-3	1	-4	78	0	-137	-1,774
Japan	220	-3,754	460	-680	0	2,913	-94	612	-28	2,724	-895	-1,782	147	-3	46	-380	475	69	-1,271	-1,221
China and Hong Kong	8,920	114	208	-92	-792	8,192	12	459	129	2,003	-23	146	283	753	182	-16	867	283	188	21,817
India	105	-524	-98	-58	-192	48	0	27	9	105	-35	-45	414	39	79	-2	353	163	-50	338
Central and Carib. Americas	2,726	-79	127	-64	-1	-13	-62	1,895	391	24	35	1	47	-25	-29	370	-58	4	44	5,333
South and Other Americas	841	-620	1,131	-63	-127	161	-222	865	649	51	-7	-6	20	6	13	10	109	1	-8	2,805
East Asia	1,410	259	370	-41	-5	3,676	90	693	113	323	330	590	481	45	195	17	805	133	178	9,661
Malaysia and Indonesia	420	-997	93	-118	-2,159	922	53	106	6	991	-125	-577	410	-27	124	-12	685	166	-762	-802
Rest of South East Asia	642	-1,091	74	-128	-1,586	1,173	-18	116	5	644	-590	-383	805	-16	51	-70	252	125	-525	-520
Rest of South Asia	496	391	0	6	2	119	30	13	9	158	9	20	111	-10	110	-2	310	30	27	1,828
Russia	148	-2,143	85	-4	-69	412	45	89	8	178	16	9	37	0	3,436	329	390	21	-2	2,986
Other East Europe	344	3,650	3	-15	-155	4	-10	7	-11	18	-6	-18	21	2,471	1,459	136	979	102	2	8,982
Rest of European Country	1,771	-4,389	310	161	378	702	49	443	139	409	190	219	86	147	386	-87	838	195	-22	1,926
Mid. East & North Africa	8	-645	324	-70	558	376	369	125	70	604	-5	-247	-153	4	2,199	348	4,300	551	228	8,943
Sub Saharan Africa	16	-433	209	-10	2	37	-13	13	49	111	3	11	43	8	21	130	56	2,423	51	2,726
Oceania countries	45	-233	17	-25	-923	336	-10	49	9	268	-163	-232	88	-3	13	21	152	34	-1,289	-1,846
Total	23,652	-28,656	7,599	-2,091	-7,288	23,964	393	11,036	4,134	12,615	-1,042	-1,352	3,263	5,632	15,524	-25,596	16,804	6,140	-3,890	**60,841**