Trade and the Greenhouse Gas Emissions from International Freight Transport

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Abstract: We collect extensive data on worldwide trade by transportation mode and use this to provide detailed comparisons of the greenhouse gas emissions associated with output versus international transportation of traded goods. International transportation represents only a small fraction (3.5 percent) of worldwide emissions, but when compared to emissions from the production of exported goods transportation looms much larger. World-wide 37 percent of trade-related emissions come from international transport. North America is especially reliant on air cargo; as a result 67 percent of its export-related emissions are due to international transport. Over 80 percent of machinery export emissions come from international transport. We then simulate trade growth associated with growing GDP and tariff liberalization to calculate emissions growth. Full liberalization of tariffs leads to transport emissions growing twice as fast as trade as trade shifts toward distant trading partners. Emissions growth from growing GDP dwarfs any growth from tariff liberalization.

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I. Introduction

International trade generates greenhouse gas (GG) emissions from two sources: the production of traded goods, and their transportation between trading partners. A large literature has focused on the emissions associated with production, examining a broad set of questions related to how trade may reallocate production between countries with differing emission intensities.[1] Emissions associated with international transportation have received much less attention.[2] Because of that, we lack systematic information regarding the magnitude of transportation emissions relative to production, and how they are distributed across trade flows.

The key problem is data. International trade makes use of a large variety of transportation modes (ships of all sizes and types, planes, trucks, rail, pipelines) with widely varying greenhouse gas emissions per quantity shipped. One kilogram of cargo flown one kilometer on a plane generates up to 200 times the emissions of that same kg-km on a bulk cargo carrier. Transportation modes are chosen by trading firms based on product characteristics (weight, value, fragility, spoilage, the need for timeliness in delivery) and geographic characteristics (land adjacency, distance to markets, existence of and access to infrastructure). As a consequence, the composition of trade has a first-order impact on the types of transportation employed and the associated greenhouse gas emissions. Put another way, a million dollars of grain shipped on rail from France to Germany may have a dramatically different emissions component than a million dollars of consumer electronics shipped on airplanes from Taiwan to the US.

The International Transport Forum (ITF 2010) has constructed estimates of the worldwide GG emissions from international transport based on fuel usage for entire fleets. While this is useful for putting international transport into aggregate perspective it is not possible to use these data to understand which trade flows are especially emissions intensive. With data on the transport emissions for each specific trade flow it would be possible to compare the relative magnitude of output and transport emissions. It would also allow a better accounting of which flows would be hardest hit by attempts at reducing emissions.

Aggregate emissions data are also not useful for calculating the likely changes in emissions growth associated with rising world trade. The reason is that trade liberalization and GDP growth are likely to lead not only to growth in the quantity of trade but to changes in its product and country-pair composition. The structure of protection is not uniform across commodities or across country pairs. This means that liberalization may result in especially large trade growth in product categories and

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[1] Examples include Ederington and Minier (2003), Babiker (2005), Levinson (2009), Levinson and Taylor (2008) among others. See also Copeland and Taylor (2004) for a comprehensive literature survey.

[2] An exception is a literature on “life cycle analysis” in which transportation is accounted for as one part of a larger production chain (see for example Jones, 2006; Sim et al., 2007; Williams (2007), Carlsson-Kanyama et al., 2003; Canals et al., 2007). Papers in this literature track every input and every aspect of production and delivery associated with a particular production (e.g. cut flowers from Kenya). While highly detailed and informative about transport’s contribution to emissions for a particular product, these studies are not useful for providing systematic information for world trading system as a whole.

between (distant) country pairs where high tariff rates previously prevailed. Similarly, GDP growth is unlikely to be uniform. Growth in distant, labor-abundant countries such as China and India may skew the commodity and country composition of trade in a way that significantly affects the emission intensity of their exports.

The purpose of this paper is to provide two exercises, both of which are novel in the literature. In the first we calculate the emissions associated with each origin-destination-product trade flow worldwide in a base year 2004. In the second, we calculate the emissions growth due to a simulated change in trade arising from tariff liberalization and GDP growth.

The calculation of base year emissions proceeds in steps. First, we collect detailed data from various national and international sources in order to describe worldwide movement of trade (expressed in weight and value units) by transportation mode. Knowing both weight and value is necessary because one million dollars of coal is vastly heavier than a million dollars of microchips, and emissions depend on weight, not value, traded. Moreover, knowing transport mode by country pair and product is critical because coal and microchips are shipped using different transportation modes, and coal moved within Europe uses a different mode of transport than coal moved from South America to Europe. Next we draw on estimates of greenhouse gas emissions associated with each transportation mode to calculate how trade volumes will combine to yield aggregate emissions for each bilateral flow. These compositional differences could be quite pronounced – trade that primarily employs airplanes will generate far greater greenhouse gas emissions than trade that primarily employs large bulk carriers or containerships.

By combining trade data by mode and emissions data by mode we provide a full accounting of the emissions associated with international transportation. This “bottom-up” accounting of emissions yields aggregate emissions that are remarkably close to matching the “top-down” accounting provided by the ITF 2010. Unlike the ITF aggregate data, these emissions numbers are specific to each origin-product-industrial sector. This allows us to calculate the emissions associated with a dollar of trade and decompose it into a production and a transport component.

International transportation represents only a small fraction (3.5 percent) of worldwide emissions, but when compared to emissions from the production of exported goods transportation looms much larger. World-wide, 37 percent of trade-related emissions come from international transport. North America is especially reliant on air cargo; as a result 67 percent of its export-related emissions are due to international transport. These numbers are even more extreme in some individual sectors: 80 percent of trade-related emissions in machinery exports come from transportation.

Our second exercise uses the GTAP CGE model to simulate the level and composition of trade growth in five distinct scenarios. Combining this with modal and emissions data we can then calculate the predicted growth in emissions from trade. Three of these simulations correspond to various liberalization scenarios proposed under the current Doha negotiations. A fourth simulates the effect of a full trade liberalization; that is, removing all existing import and export tariffs and subsidies. The final scenario leaves all existing barriers in place and examines only changes due to differential growth rates in country level GDP through the year 2020. In each scenario, we generate the predicted growth in output for each country x sector, and in bilateral trade flows for each of the 1600 country pairs available in each sector.

Our primary findings are as follows. The three Doha round liberalization scenarios generate very small changes in output, exports, and greenhouse gas emissions. The most extensive of the three results in only a 0.9 percent rise in trade, a 1.3 percent rise in transportation services and a 2.4 percent increase in international transport emissions. Full liberalization results in a 5 percent increase in trade, concentrated in those products (agriculture, textiles and wearing apparel) that are subject to the highest rates of protection. More importantly, liberalization eliminates tariff preferences enjoyed primarily by nearby trading partners (e.g., NAFTA and the EU). This results in a shift in trade away from proximate partners and toward distant partners, especially those who cannot be reached by land transport. Growth in transportation services (measured in kilogram-km terms) rises faster than trade, with a world-wide contraction in the use of road and rail transport and an expansion in air and ocean transport. Combining this information with emissions data by mode, we calculate that CO2 emissions associated with international transportation would rise twice as fast as trade due to expansion of air cargo. In contrast, production related emissions would actually fall due to tariff liberalization and a reallocation of production toward more energy efficient locations.

In contrast to the modest effects from tariff liberalization, output growth leads to profound changes in trade and emissions. Exports rise at 3.36 percent per year, transport emissions rise at 3.4 percent per year, and output related emissions at 4.3 percent per year. Trade shifts toward rapidly growing China and India and with it comes a rising reliance on air and sea transport. Looking over all traded goods, the greater is the transport emission intensity of a trade flow in the base year, the faster trade grows.

The paper proceeds as follows. Section two describes the methodology. Section three describes the construction of the main data components for our exercises. Section four describes the data in the base year, and discusses the current contribution of international transportation to greenhouse gas emissions from international trade. Section five provides simulations of trade growth, and calculations of how this growth would affect modal use and emissions. Section six concludes.

II. Methodology

There are two ways to calculate greenhouse gas emissions associated with international transport. The first, employed by the International Transport Forum (ITF 2010), gathers data on fuel consumption from the International Energy Agency (IEA 2010), along with information on GG emissions by fuel type. Since planes, boats, trucks, and trains use different fuel types, it is a simple matter to calculate emissions associated with aggregate fuel consumption by mode. By tracking actual use of fuel this “top-down” approach is a very accurate way to assess aggregate emissions. There are several drawbacks. One, it is not possible to assess where or how this fuel was used. A containership refueling in Rotterdam could be carrying cargo of any type between any country pair in the world. Two, it is not possible to calculate international transport emissions associated with road and rail transport as their fuel usage is indistinguishable from domestic road and rail usage.

We use a “bottom-up” approach in which we construct the emissions associated with a trade flow by calculating the quantity of transportation services for that flow provided by each transportation mode, and multiplying by emissions per unit of transportation services. Denote E_{odg}^{T} as the emissions associated with transporting good g from origin o to destination d. VAL is the value of that flow, and WV is the weight to value ratio so that $VAL_{odg} * WV_{og}$ is the quantity of the flow in kilograms. A country pair may ship product g using multiple transportation modes. The quantity share of mode m in that flow is QS_{odg}^{m}, so $VAL_{odg} * WV_{og} * QS_{odg}^{m}$ gives the quantity of the flow for each mode, in kg. Multiplying by $DIST_{od}^{m}$ the distance traveled from o to d for mode m gives us a measure of transportation services, for each mode, measured in a common unit (one kg of cargo moved one kilometer). Finally, multiplying by e^{m}, the greenhouse gas emissions produced by mode m when providing one kg-km of transportation services, and summing over all modes yields the total emissions associated with that trade flow.

$$(1.1) \qquad E_{odg}^{T} = \sum\nolimits_{m} VAL_{odg} * WV_{og} * QS_{odg}^{m} * DIST_{od}^{m} * e^{m}$$

Trade flows are most commonly reported in value terms. Pulling the value of the trade flow out of this summation we can decompose the quantity of transportation emissions from the flow into a scale measure and an intensity measure

$$(1.2)\ E_{odg}^{T} = VAL_{odg} * e_{odg}^{T} \quad where \quad e_{odg} = \sum\nolimits_{m} WV_{og} * QS_{odg}^{m} * DIST_{od}^{m} * e^{m}$$

Using this basic decomposition we can perform a number of comparisons and calculations. For example, we can compare the transport emissions from exports across countries. Summing over importers and products, an exporter o’s emissions are

$$(1.3) \qquad E_{o}^{T} = VAL_{o} * e_{o}^{T} = VAL_{o} * \sum\nolimits_{dg} s_{odg} * e_{odg}^{T}$$

This depends on its scale of trade and the transport emission intensity of a dollar of trade. The latter is a trade-weighted average of emissions from individual flows. If an exporter engages in trade with more distant partners, trades heavier goods, or uses aviation more than maritime transport it will have a higher aggregate transport emission intensity. We can provide similar aggregations by importers (aggregating over exporters and products) or by products (aggregating over country pairs).

We can also use this decomposition to compare the emission intensity of trade arising from two distinct sources: production of traded goods and transport of traded goods. Begin by writing the emissions from output of good (or service) g in country o as the product of output (in dollars) and emissions per dollar of output,

$$(1.4) \qquad E_{og}^{Y} = Y_{og} * e_{og}^{Y}$$

so that aggregate emissions in a country are an output weighted of emissions for each activity, $E_o^Y = Y_{og} * \sum_g s_g * e_{og}^Y$. Aggregating again over all countries yields worldwide emissions.

Existing efforts to evaluate international transport emissions have compared all transport to emissions from all other sources. Consider Table 1, which contains information on output and transport emissions for various years drawn from ITF (2010) and International Energy Agency sources. We focus on 2004, which will be the base year used in our calculations. International transportation (defined as international maritime plus international aviation, but excluding international road and rail transport) is responsible for only 3.46% of total emissions. This seems trivial, but total emissions include many activities (e.g., residential energy usage, domestic transportation), which are not directly related to output or trade. If we instead measure each component Y_{og}, e_{og}^Y directly, we can compare the emissions from the production of tradable goods to the international transportation of those goods. The IEA estimates that industrial production represents only 20% of worldwide emissions. Using this figure, international transport of merchandise represents 17.29% of the emissions from industry. Going further, most output emissions are unrelated to trade. For example, if only 10% of steel output is traded, then 90% of the output emissions from steel correspond to a domestic flow.

By writing both output and transport emissions in per dollar terms, we can calculate the contribution of each emission component to the total emission associated with a particular trade flow. For any particular o-d-g flow we have:

$$E_{odg} = \left(e_{odg}^T + e_{og}^Y\right) * VAL_{odg} \tag{1.5}$$

To give a rough idea of the relative contribution of transport based on ITF and IEA data, Table 1 reports calculations for transport emissions per dollar of trade using the worldwide emissions and trade totals. International transport now represents 38.7% of total emissions per dollar of trade. Of course, these are rough aggregated numbers, but they suggest international transportation could be responsible for a significant fraction of overall trade-related emissions.

In our second exercise we will use a CGE simulation to generate changes in the value of trade resulting from tariff liberalization and GDP growth. Combining this with our scale vs. intensity decomposition we can calculate the effect of growing trade on emissions growth. Fixing the emission intensity of a particular output sector o-g, the growth in output related emissions is:

$$\Delta E_{og}^Y = \Delta Y_{og} * e_{og}^Y \tag{1.6}$$

Fixing the emission intensity of a particular odg trade flow, the growth of trade-related emissions is then

$$\Delta E_{odg}^T = \Delta VAL_{odg} * e_{odg}^T \tag{1.7}$$

This exercise holds fixed the modal shares for each o-d-g flow, and the emission intensity of each mode. The key point in both instances is that we do not model how changes in fuel prices, spurred either by rising demand for fuel or changes in carbon/fuel taxes, affect mode-specific prices. Nor do we examine endogenous technological change prompted by changing fuel prices or taxes.

Fixing modal shares for each o-d-g flow yields a reasonable approximation of aggregate changes in modal use and emissions in two cases. One, if tariff liberalization or GDP growth does not generate large changes in relative transportation prices (e.g. the price of air versus ocean shipping), then we would not expect modal shares within an o-d-g flow to change much. This would be the case if there are few aggregate changes in modal use, or if trade growth does not affect input costs differentially across modes.[3] Two, suppose that modal use varies primarily across (rather than within) o-d-g flows due to immutable geography, infrastructure, and product characteristics. For example, land-adjacent countries will continue to move goods via road and rail independent of ocean shipping prices while countries separated by an ocean will be unable to use road and rail. Similarly, product weight will force grain onto bulk cargo carriers regardless of the price of air cargo. In these cases, small changes over time in modal use within each o-d-g flow will be swamped by changes in the trade shares of flows that use one mode more than another.[4]

III. Data

Next, we describe the five main data components necessary to describe emissions from output and international transportation in the base year, and to simulate changes in emissions associated with trade growth. These data components are: simulated trade growth; greenhouse gas emissions associated with output; the weight and value of trade for each bilateral pair and product; the modal shares for international transportation employed for each bilateral pair and product; and finally the greenhouse gas emission intensity of each transportation mode.

A. Simulated Trade Growth

We wish to simulate the changes in worldwide output and trade (ΔY_{og} and ΔVAL_{odg} in equations (1.6) and (1.7) respectively) associated with various tariff liberalization and output growth scenarios. This requires the use of a computable general equilibrium (CGE) model of trade. We employ version 7 of the GTAP model, which is widely used in policy circles. Critically for our purposes the GTAP database contains detailed information on energy usage and greenhouse gas emissions. A highly detailed

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[3] Put another way, the exercise focuses entirely on how trade affects greenhouse gas emissions of international transport while ignoring any feedback effects from international transport's fuel use and emissions to trade. One can imagine a different, and far more ambitious, exercise that would attempt to assess how carbon taxation would affect fuel prices and therefore modal choice, and how that would feedback into changes in trade patterns. That would be a n interesting question to study, but not it is the focus of this paper.

[4] We also hold fixed the weight/value ratio of trade for a given flow. This is justified by a similar argument, that small changes over time in weight/value within an odg flow will be swamped by changes in the trade shares of light versus heavy flows.

description of this model can be found in Hertel and Tsigas (1997). We briefly summarize key characteristics here.

Within each sector firms are constant returns to scale with a production structure that is Leontief in factor inputs (labor, capital, and land) and intermediate inputs including energy commodities (more on this below). Substitution between factor inputs is governed by a CES structure, as is substitution between intermediate inputs that are Armington differentiated by origin. On the consumption side, households have Cobb-Douglas preferences over consumption, government spending and saving. Demands over consumption goods employ a CDE (constant difference of elasticities) form, and households regard the output of each source country as Armington differentiated.

At its maximum disaggregation, GTAP 7 allows one to model production and trade for 57 traded and non-traded sectors between 113 countries. While it is not computationally feasible to run trade experiments with the full 113 country x 57 sector version of the model , GTAP allows for flexible aggregation across regions and sectors in order to examine certain especially interesting subsets of the whole dataset. For current purposes, we employ a 40 region, 29 sector version of the model, the detailed listing of which is reported in Appendix Tables 1 and 2. This particular aggregation scheme was chosen to serve two purposes. One, countries and sectors with “similar” transportation characteristics are aggregated together. For example, all bulk agriculture, which relies heavily on international ocean transport, is aggregated into one category while processed agriculture, which is more likely to employ air transport, is aggregated into a second category. Two, we employ country level aggregation in cases where we have detailed weight/value and transportation mode data, and broader geographic aggregation for regions where these data are lacking. For example, we represent the Middle East and Africa in only 3 aggregated regions, while Europe is represented with 15 individual countries and 3 aggregated regions. This allows us to minimize the amount of imputation that must be employed to complete the database.

In our simulations we explore a number of scenarios related to tariff liberalization and to output growth.

Tariff Liberalization Scenarios

To capture possible effects of trade liberalization we explore four scenarios. Three of these are “likely” tariff cuts under current Doha round negotiations. The fourth is a full liberalization scenario in which all import and export tariffs and subsidies are set to zero.

There have been a wide variety of liberalization proposals as part of the Doha round. Ten of these proposals have been modeled by CEPII and incorporated into the GTAP model. There are subtle differences across these proposals, so we choose a representative three, referred to in Minor (2006) as Doha Scenarios 4,5, and 9. Scenarios 4 and 5 focus on agricultural market access only, while scenario 9 accounts for both agricultural and non-agricultural market access (NAMA). These scenarios are chosen because their design is closest to the proposals currently under consideration.

Scenario 4 and 5 are both based on the Harbinson proposal which consists of applying proportional tariff cuts on four tiers of tariff ranges. Tariff ranges and cuts in each tier vary between developing and developed countries. The table below is drawn by Minor (2006) and shows the Harbinson tiered tariff cutting formula for agriculture in scenario 4. The tariff cuts are highest for developed countries ranging from 40 to 60 percent. Developing countries tariff cuts in each tier are about two thirds those in the corresponding tiers of developed countries.

Tier	**Developed Countries**		**Developing Countries**	
	Tariff Rate Range (%)	Cut (%)	Tariff Rate Range (%)	Cut (%)
1	< 15	40	< 20	25
2	15-90	50	20-60	30
3	> 90	60	60-120	35
4	--		> 120	40

Scenario 5 is the same as scenario 4 but allows countries to avoid the application of the tariff cuts on 2% of sensitive products. In practice, the chosen exceptions are concentrated in ‘processed agriculture’.

Scenario 9 adds non-agricultural market access[5]. The non-agricultural tariff cuts are nonproportional, so that peak tariffs are reduced more than lower tariffs. Non-linear tariff cuts formula are usually referred as Swiss-type. While the adoption of Swiss-type formula on non-agricultural products is agreed among negotiators the exact type is not. Our scenario assumes the Girard (WTO 03-4322) formula:

$$T_1 = \frac{B \times T_a \times T_0}{B \times T_a + T_0}$$

Where T_1 is the new bound tariff rate, B is the coefficient to be determined for reductions, T_0 is the base bound rate, and T_a is the average of base bound rates for NAMA products. B is equal to 1 for developed countries and 2 for developing countries.

GDP Growth Scenarios:

Tariff Liberalization may lead to modest increases in trade, but rising output is likely to lead to much more rapid trade growth. Moreover, output growth is likely to be asymmetric with some developing countries such as China and India growing much faster than developed countries. To experiment with output growth we use a specialized version of the GTAP model called GDyn (or Dynamic GTAP). This version of the model differs in several important aspects. One, it contains detailed projections of GDP and factor endowment growth rates for each country in the database (Walmsley 2006). Two, it explicitly models the dynamics of capital accumulation and allows for international capital mobility.

We use this model to provide two GDP growth scenarios

1. Growth through factor neutral technological change. In this case we take the change in real GDP (projections drawn from Walmsley 2006 and reported in Appendix Table A.3.) as

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[5] The agricultural market access underlying this scenario assumes instead of the Harbinson formula an harmonizing formula.

exogenous, fix the quantities of endowments, and solve for a Hicks neutral technological change that would reconcile the exogenous GDP growth with other model values. The point of this exercise is to focus entirely on how changes in the scale of output will drive changes in trade and emissions.

2. Growth through factor accumulation. (RESULTS NOT COMPLETE IN THIS DRAFT). In this case we take real GDP growth as exogenous, but now we allow factor endowments to change in line with database projections. Again, the Hicks neutral technological change variable reconciles these changes with other model values. However in this case the technology parameter does much less work as cross country differences in GDP growth are largely accounted for by differences in capital accumulation. The point of this exercise is to combine scale changes with changes in comparative advantage that result from differential capital growth rates.

B. Greenhouse Gas Emissions from Output

The GTAP 7 database provides data on greenhouse gas emissions produced by each sector g in each country o, E_{og}^{Y} in equation (1.4). We briefly summarize how these data were constructed, and direct readers to more detailed discussions available from Lee (2008) and Rose et al (2010). For each o-g pair, the database contains information on use of six energy inputs (coal, oil, gas, petroleum products, electricity, and gas distribution). Energy use differs across countries and sectors as a function of the energy intensity of production, the efficiency with which energy is used, and the availability of energy inputs in the respective country. Using a standard formulation provided by IPCC (1997) guidelines, the quantity of energy inputs are then converted into CO2 emissions. Finally, these data are supplemented by calculating non-CO2 greenhouse gases emitted as a byproduct of production (primarily in agriculture). These are converted into CO2 equivalents based on their global warming potentials, following the methodology in USEPA (2006).

Combining these data we have total greenhouse gas emissions for each country o and sector g. To provide comparisons to our transportation emissions, we describe these as emission intensities per dollar of output (e_{og}^{Y} in equations (1.5) and (1.6)) by dividing total emissions for o-g by the market value of output o-g.

C. The Weight and Value of Trade in the Base Year

As is the case with most trade-focused liberalization experiments, output and trade are expressed in value terms. However, to calculate the effects on transportation demand, fuel usage and greenhouse gas emissions, it is necessary to convert these values into a physical unit of measurement that is consistent across countries and products, and is meaningful from a transportation perspective. The most feasible conversion is to express trade in terms of kilograms shipped (or in kilograms-kilometers shipped). This is not a perfect measure, as it neglects transportation relevant issues such as product bulk and the need for special packaging or refrigeration. But it is the best universal measure that can be employed.

For calculating trade in kilograms (or kg-km), we need data on weight-to-value ratios at detailed level. We draw on three primary data sources:

1. US Imports and Exports of Merchandise. These data contain US imports and exports with every partner country worldwide at the 10 digit level of the Harmonized system. They include information on whether trade took place via airplane, ocean-going vessel, or overland, with separate values and weights for each mode. The data are available on DVD's from the US Bureau of the Census.

2. Eurostats data. These data include information on the imports and exports of the 27 EU countries with each other and the rest of the world, by value and by weight in kilograms. For trade outside the EU data are reported at the HS6 level, disaggregated by transportation mode.[6] Data on intra-EU trade by transport mode are reported at the 3 digit level of the NSTR and were compiled on special request by statisticians at Eurostats.

3. ALADI trade data. These data include the imports of 11 Latin American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela) from all exporters worldwide, at the HS 6 level, disaggregated by mode of transport and containing data on traded product value and weight in kilograms.

The bilateral pair coverage represented by these three datasets is displayed in Appendix Table 1. Because the US and European data include both imports and exports all countries worldwide are represented extensively in the data. Altogether approximately two-thirds of world trade by value is covered.

In principle one could provide the calculations on weight/value and transportation mode at any level of regional or product aggregation, and our trade and transport data are available at a very detailed level (HS6 products for over 4000 bilateral country pairs). The limiting constraint in our case is the level of aggregation at which we can provide simulated trade growth in a computationally feasible world CGE model. As a consequence it is necessary to concord the data to the 23 merchandise trade sectors used by the GTAP model. This means that for each importer and exporter there may be several hundred HS codes corresponding to a single GTAP sector such as "electronic equipment". To arrive at a weight/value ratio for each exporter and product, we separately sum the weight of trade and the value of trade and express them as a ratio. This is equivalent to a share-weighted average of the weight/value ratio for each product traded by that exporter. More formally, let k represent an HS6 product contained in GTAP sector g, traded between origin o and destination d. To get the weight/value ratio for each origin and GTAP sector

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[6] These data are available for download from Eurostats, at: http://europa.eu/estatref/download/everybody/comext/MOST_RECENT_COMEXT_DATA/transport_HS/

$$WV_{og} = \frac{\sum_d \sum_{k\in g} WGT_{odk}}{\sum_d \sum_{k\in g} VAL_{odk}} = \sum_d \sum_{k\in g} \frac{WGT_{odk}}{VAL_{odk}} s_{odk}$$

where s_{odk} is the share of observation o,d,k in trade for origin o and GTAP sector g.

Given our data it would be possible to have separate weight/value ratios for each exporter-importer-sector (o-d-g) triplet. However, we chose to use the more aggregated exporter-sector approach for two reasons. One, because we do not have weight of imports data for all countries in the 40 country GTAP aggregation, it would be necessary to rely on exporter-product averages for the countries not explicitly represented. For consistency we employed the same exporter-product averages throughout. Two, trade by weight is not measured as carefully as trade by value. In the European data in particular, no weight data at all are reported in roughly 20 percent of observations. (These cases are excluded from the construction of the aggregated variable.) Relying on more aggregated observations smoothes out these measurement errors.

For reference we report data by commodity in Appendix Table 4. This includes initial tariff rates and weight/value ratios (both as a trade-weighted averages over all country pairs), along with the share of each commodity in world output, world trade by value, and world trade by transportation services units (kg-km). Of interest, some of the goods that represent a larger value share in trade (electronic equipment and machinery) represent a significantly smaller share in transportation services. This reflects large differences in weight/value between these manufactured goods and heavy products such as bulk agriculture, minerals, and oil.

D. Modal Usage in the Base Year

For every kg shipped, planes use more fuel and generate more greenhouse gases than trucks, which use more fuel and emit more than large containerships. Knowing the intensity with which trading countries employ planes, trains, and automobiles, and how modal use will shift as the composition of trade changes is critical for calculating emissions changes.

The data for this exercise come from the same three sources as the weight/value data described above. Each of those datasets contains information on the weight and value of trade by origin-destination-product , with product measured at the HS6 level for US, ALADI and EU trade with non-EU partners, and at the NSTR 3 digit level for intra-EU trade. To construct modal value shares, we sum product value over all product codes traded between o-d that fall under each GTAP sector grouping and express that sum as a share of total traded value between o-d. Modal weight shares are constructed similarly by summing weights. Modal weight-distance shares take this value and multiply by the distance between o-d.

Several challenges remain. First, as noted above, the weight field is missing for roughly 20 percent of EU observations, though these tend to be relatively small value flows. These weight=0 observations are excluded from the summations of both weight and value.[7]

Second, unlike the EU and ALADI data, the US data on overland trade do not provide further disaggregation into rail and road modes. To provide this split we employ data on US imports and exports within North America taken from the Transborder Surface Freight Data. These data have rail v. road splits, but are more aggregated at the HS2 level. We take each land-based trade flow from the more disaggregated HS 10 data and divide it using the splits found in the corresponding HS 2 data. We then aggregate to the broader GTAP 27 data.

Third, because modal usage is central to this exercise it is necessary to estimate modal shares for the roughly one-quarter of world trade where no direct information on modal use is available. In these cases we estimate modal shares as a function of geography, country, and product characteristics basing our estimation sample on those country pairs that do report modal data. Details are provided in Appendix 3.

E. Greenhouse Gas Emissions by Transport Mode

We draw on data from several studies to calculate emissions per kg-km of cargo moved by each of the four transport modes: ocean, air, rail, and road.

The most recent and comprehensive study for maritime transport comes from "Ship Emissions Study", National Technical University of Athens Laboratory for Maritime Transport (2008). It reports emissions in grams of CO2 per tonne-km shipped for many distinct ship types, as well as variability across vessels of different sizes within each type. In Table X, we reproduce the fleet averages for six ship types.[8] The University of Athens research is the only study, to our knowledge, that produces detailed breakdowns of CO2 per tonne-km shipped by ship type. Several other studies (Kristensen 2006, Giannouli and Mellios, 2005) provide data that is specific to containerized cargo, and they arrive at similar numbers for the container fleet.

To apply these maritime emissions to our data, we split the GTAP sector commodities into ship type as follows.

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[7] This will not bias the results unless there is a systematic relationship between being excluded and the employment of a particular transport mode. If there is a systematic relationship, this will tend to understate both the value share and the weight share of that mode by small amounts.

[8] In general, CO2 emissions per tonne-km shipped are much lower for larger vessels within each type. For example, post-Panamax (> 4400 TEU) containerships produce 1/3 the emissions of a less than 500 TEU feeder ship. Because we have no data on the ship size composition of flows, we employ fleet averages for each fleet type. The study also provides data for highly specialized ship types such as Reefers and Ro-Ros. We do not employ this data as our broader trade aggregates contain a mix of goods that would employ these specialized types as a small subset of goods that generally employ container vessels.

Ship Type	GTAP Sectors
Bulk	Bulk agriculture, forestry, minerals, coal products
Container	Processed agriculture, fishing, textiles, wearing apparel, leather products, wood products, paper products and publishing, ferrous metals, metals nec, metal products, motor vehicles and parts, transport equipment nec, electronic equipment, machinery and equipment, manufactures nec
Oil Tanker	Oil
LNG	Gas
LPG	Petroleum
Chemical	Chemical products

For rail and road transport we rely on estimates from Giannouli and Mellios, European environmental agency, 2005. Note that these estimates are for transport within the EU, and so presumably rely on relatively efficient rail and truck transport.

There are few detailed studies of emissions associated with air cargo and these arrive at widely varying estimates of emissions per tonne-km. A Maersk 2007 pamphlet cited in the University of Athens study reports that a Boeing 747-400 emits 552 grams of CO2 per tonne-km shipped. A California Climate Change pamphlet for 2006 reports emissions per tonne-km shipped ranging from 476-1020 grams of CO2. Finally, 2007 data from the Air Transport Association of America shows that US cargo airlines used 163.6 gallons of jet fuel per thousand ton-miles shipped. Converting gallons of jet fuel into grams of CO2 and cargos into tonne-km, we calculate carbon emissions of 963.45 grams of CO2 per tonne-km.

We also attempted to construct an independent estimate of CO2 emissions associated with air cargo using data taken from Aircraft Economics, 1999. “Freighter Cost Comparisons”. This source provides data for 14 major cargo plane types including total fuel use, revenue ton-miles flown, and share in the fleet. Combining fuel use, emissions per gallon of jet fuel, and ton-km flown it is possible to construct a measure of average CO2 emissions per tonne-km flown. The numbers range from 493 to 1834, depending on the plane type and how it was used (i.e. for short v. long haul cargo carriage). For comparison, the calculation for the Boeing 747 using this method yields emissions of 700 grams of CO2 per tonne-km which is close to the Maersk study. Taking a weighted average of these emission numbers over the fleet shares reported, we arrive at an average emissions of 972 grams. Finally, if we update the fleet composition using 2008 shares (from ATA) we arrive at average emissions of 912.1 grams. The wide range suggested by these numbers is likely due to fleet composition -- as with maritime data, calculations of fuel use and emissions are sensitive to vessel size and use.

In the calculations that follow we employ 552 as a "LOW" emissions scenario for air. This corresponds to the use of the most efficient aircraft on the longest flights. We use 950 as a "HIGH" emissions scenario, and it corresponds to use of a mixed fleet of smaller planes on shorter flights.

IV. Modal Use, Transport and Output Emissions in the Base Year

We begin our discussion of the results by focusing on data in the base year. The results of our data collection generates a full matrix of modal shares for each origin-destination-GTAP sector by value, weight, and transportation service units (kg-km). In the interests of space we provide some aggregations of these shares. Table 2 provides modal shares by region (importer, and exporter), and Table 3 provides modal shares by traded goods sector. In each case shares are provided by trade value and KG-KM.

A few things are notable. There are large differences across regions in the value shares of the transportation modes that largely reflect geography. For example, North America and Europe, with important land-adjacent trade partners, rely much more heavily on road transport.[9] The split between air and ocean is especially important as it reflects the largest gap (100-200 fold) in emission intensities. The difference across regions is most pronounced on the exporting side. Excluding land-based modes, air transport represents 48 percent of international cargo for North America, 27 percent for Europe and Asia, and much smaller shares for the rest of the world.

It is also instructive to contrast the value of trade with the transportation services (KG-KM) employed by trade. Here, sea transport dominates with 94 percent of transportation services provided. Products that are heavy, and that are transported long distances, are much more likely to be sea-borne. The largest difference relative to value shares comes in the use of road-based transport: while it represents nearly half of European imports by value it is only 5 percent of European imports by KG-KM. While road transport constitutes a large share of value and weight moved in European trade, it is concentrated in the trade of proximate partners. As a result, road transport represents a very small share of kilogram-kilometers shipped.

We see in Table 3 that a similar composition issue explains the difference in air shares when calculated on a value vs. a KG-KM basis. High weight/value goods move by sea and low weight/value goods move by air. Air shares by value are then quite substantial for fishing and for many manufacturing products, amounting to 20 percent of world trade by value. But on a per kg-km basis air shipping is less prominent.

Emissions Data

We turn next to emissions. Recall that we have constructed emissions for each trade flow by calculating the KG-KM of transportation services provided by each mode, then multiplying by emissions per KG-KM for each mode. If we add this up over all trade flows we have an alternative estimate of total

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[9] Most of Asia has very small shares of land transport because the largest trading partners are separated by (short) stretches of ocean. South America, for which land transport is actually an option has rather low land transport shares, probably because economic activity is concentrated on coasts rather than in the interiors close to land borders. When we disaggregate to the country level there are more dramatic differences. Europe as a whole has very high shares of rail and road transport, except for countries like the UK, Ireland, and Finland.

CO2 emissions from international transport. How does this bottom up approach compare to the top down ITF (2010) approach that simply collects fuel usage? The answer is: surprisingly well. In 2004, the ITF calculates that international aviation and maritime transport was responsible for 910 million tons of CO2 production. Our approach arrives at a number ranging from 738 tons to 1015 tons depending on whether we use the HIGH or LOW aviation intensities.[10]

Our rough estimates in Table 1 drawing on the ITF aggregate numbers suggested that international transport was responsible for 38.7 percent of trade-related (output + transport) emissions. These numbers are incomplete because they omit road and rail transport from the numerator, and they omit certain emission intensive industries from the denominator. Using our more comprehensive transport and output emissions data, we calculate that international transport is responsible for 37% of trade-related emissions.

We do a reasonably good job of matching the ITF aggregate numbers which gives us confidence that our estimates for disaggregated flows will also be informative. We have transport emissions for each of 35,880 origin-destination-industry trade flows, and output emissions for 920 country-industries. How do these compare?

Emission Intensity CO2 grams/$	Means			
	Simple	Trade-weighted	Median	ST DEV
Transport	582.2	150.2	113.0	5318.9
Output	581.5	289.2	137.3	1754.6

The emission intensities (or emissions per dollar of trade or dollar of output) are quite similar. The simple means are very close, with output emission intensities higher for the median observation and on a trade weighted basis. Transport intensities are also more highly variable. We plot the distribution of emission intensities in Figure 1. In both cases there is a wide distribution, ranging from close to zero grams of carbon per dollar to well over 2 kg of carbon, and the distributions overlap considerably.

In Figures 2a,2b we examine the correlation between transport and output emissions for the same trade flow. Figure 2a shows (log) total emissions associated with a trade flow while Figure 2b shows emission intensities. Points lying on the 45 degree line correspond to flows in which the output and the transport emissions are identical. A few things are noteworthy. One, total emissions from transport and production are highly correlated. This is perhaps not too surprising because the value of the trade flow

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[10] We intend to refine these numbers in future drafts as follows. If we focus only on aviation and use the LOW emission intensities, our aggregate emission output is 385, remarkably close to the ITF numbers of 389 tons. Our ocean values are considerably lower -- 352 tons compared to 520 for the IITF. This is likely because in this draft we have used straight line distances between countries. A significant fraction of maritime transport takes very indirect routes between countries. Using ship schedule data it is possible to calculate actual voyage distances which could easily add 50% or more to the mileage total and therefore 50% to the emissions totals.

is a common element in both emission types, but when we focus on emissions intensities we still see a correlation.

Note that in Figure 2b each o-g output emission is associated with up to 40 o-d-g transport emissions. This is useful for seeing the extent of variation in transport emissions around the output emissions. For o-g observations with low output emissions, all transport emissions lie above the 45 degree line and so exceed output emissions; for the mid-range of output emissions, transport emissions are distributed symmetrically around the output emission; for high levels of output emissions, all transport emissions lie between the 45 degree line. Also notable is the extent of variation. We saw above that the standard deviation for transport emissions far exceeds that for the output emissions. The scatter shows this pattern clearly – within each origin-sector there is a huge variation across partners in the emissions associated with transport reflecting differences in distance and transportation modes. The implication is that a change in the partner composition of trade can have a much larger impact on overall emissions than changing what is produced or who produces it.

Next we are interested in the contribution of transport emissions to total emissions when calculated on a common per dollar basis. Figure 3 provides this comparison by industry. We aggregate transport emissions for each industry by summing over all country pairs. Taking the transport emissions for each industry and dividing by the value of trade yields a (weighted average) transport emissions intensity for that industry. A similar procedure yields the average output emissions intensity. Adding these together as in equation (1.5) enables us to calculate the share of transport emissions in total trade-related emissions for each industry (data in grey, scale displayed on the right vertical axis). The chart ranks industries from smallest to largest in terms of the share of transport emissions. For perspective we also display transport emissions for that industry as a share of total transport emissions (data in blue, scale displayed on the left vertical axis).

Two kinds of industries generate the largest share of transport emissions. Recalling Appendix Table 4, a few “heavy” products (bulk agriculture, oil, minerals, petroleum and coal products, chemical products) were responsible for three-quarters of transportation services measured in KG-KM, despite being a much smaller share of trade by value. These products also show up toward the higher end of emissions shares. However, the top two industries are very light products (electronics, machinery) that are much more likely to be shipped via emission intensive airplanes.

Recall that worldwide transport is responsible for 37 percent of trade related emissions. At the industry level we see wide dispersion in these numbers – over 80 percent of the trade-related emissions of machinery and metal products come from transportation.

In Table 4 we provide similar calculations, aggregating transport and output emissions by regional groupings. First we show the contribution of each region to total world emissions, both for transport and for industrial output. On the import side, North America, Europe and Asian are responsible for 85 percent of total transport emissions. This largely reflects the size of these country groupings and their dominance of world trade. More surprising is transport emissions on the transport side, where North

America is responsible for a remarkable 44 percent of total emissions. This is a consequence of an unusually large reliance on air cargo in North American exports.

We next calculate emission intensities for both transport and trade, measured in grams of CO2 per dollar of trade. These are reported in levels and for transport as a share of the total. Recalling that transport is responsible for 37 percent of trade-related emissions worldwide, at the region level this number ranges from 18 percent to 60 percent (on the importing side) and 20 to 65 percent on the exporting side. The emission intensity of export transport for North America is substantially higher than for any other region, and nearly 8 times higher than Europe. Two-thirds of trade-related emissions from North American exports come from transport.

A clear implication of these numbers is that both production and transportation emissions should be considered when evaluating policy changes designed to curtail emissions. In some countries the impact will be felt most acutely on the production side, whereas in countries like the US, the main effect will primarily be on transport. We can also look at these numbers in order to compare the total emissions associated with a dollar of trade. As an example North American exports are “only” 73 percent more emission intensive than European exports if we focus only on output emissions. But when we include transport emissions in the total, they are now 3.5 times greater.

V. Trade Growth and Changes in International Transport Emissions

In this section we describe four tariff liberalization and one output growth simulations. With any such simulation in a large scale CGE model there are literally thousands of changes occurring in trade, output, factor prices, factor usage and so on. We are concerned here only with how these changes interact with transport usage and emissions intensity.

Table 5 summarizes change in output, exports, and emissions under each of the five scenarios, and Table 6 reports changes in modal use. Changes in output value, output emissions, and export values come directly from the GTAP model. Combining these with our data on trade weight/value and distance we calculate changes in exports by weight and by transportation services. Combining changes in transportation services with data on modal use and emissions we calculate changes in modal use and emissions.

The three Doha scenarios are largely uninteresting from a transport and emissions perspective. Simply, these liberalization efforts are so modest that they yield little growth in trade, in transport, or in emissions. The most far reaching scenario yields a 0.9 percent increase in trade by value, a 1.3 percent increase in trade by kg-km, and a 2.4 percent rise in transport emissions. Accordingly, we will dispense with discussing Doha hence forth.

The full liberalization scenario eliminates all import and export tariffs and subsidies. While this is perhaps not especially likely, it gives us at least something to look at. Full liberalization results in a 5 percent increase in trade, concentrated in those products (agriculture, textiles and wearing apparel) that are subject to the highest rates of protection.

More importantly, liberalization eliminates tariff preferences. Current tariff rates are not set uniformly across trading partners and significant preferences are given to partners within trading blocs such as the EU and NAFTA. Because trading blocs tend to be geographically concentrated, tariffs tend to be much lower for more proximate partners and especially for land-adjacent partners. This can be shown using a simple regression of tariffs on (log) distance between partners. Let o denote origin (exporting) country, d denote destination (importing) country, g denote GTAP sector, and incorporating an importer-product fixed effect, a_{dg}, we find

$$TARIFF_{odg} = .88 + .022 \ln DIST_{od} + a_{dg}$$

Similarly, using a dummy variable for land adjacent partners

$$TARIFF_{odg} = 1.055 - .045 BORDER_{od} + a_{dg} \text{ C}$$

Controlling for the average level of tariffs set by an importer in a sector, doubling distance increases the tariff rate by 2.2 percentage points; the average tariff for non-adjacent partners is 5.5 percent, while the tariff for adjacent partners is less than 1 percent.

This is an important phenomenon from a transportation perspective because land-adjacent and otherwise proximate countries trade very differently from more distant partners. Rail and road transport dominate international trade between land-adjacent countries. And the choice of air versus ocean transport depends critically on the distance between (non-land-adjacent) countries. Since preferential tariff rates currently favor proximate partners, reducing these rates to a uniform zero tends to create more trade at a distance.

This results in a shift in trade away from proximate partners and toward distant partners, especially those who cannot be reached by land transport. Growth in transportation services (measured in kilogram-km terms) rises faster than trade, with a world-wide contraction in the use of road and rail transport and an expansion in air and ocean transport.

Combining this information with emissions data by mode, we calculate that CO2 emissions associated with international transportation would rise twice as fast as trade. Some of this is due to a rise in trade at a distance and some is due to the expansion of air cargo. In contrast, production related emissions would actually fall due to tariff liberalization and a reallocation of production toward more energy efficient locations.

In contrast to the tariff liberalization simulations, the GDP growth scenario yields profound changes in output, trade, and greenhouse-gas emissions, all growing at between 3 and 4 percent per annum. Tariff liberalization created trade growth biased toward long distance trade because of the erosion of proximity-based tariff preferences. The GDP growth experiment creates trade growth biased toward long distance trade because the fastest growing countries (China, India) are far away from other large markets. As with tariff liberalization there is faster growth in air and sea transport relative to rail and road transport. Apart from these distance-based changes, the GDP growth scenario results in relatively little compositional change. The reason is that, in the simulation, we fed all the size changes through TFP so that we did not fundamentally change factor based comparative advantage. In a subsequent draft we will allow different rates of capital growth and we expect this will lead to more profound compositional shifts.

These aggregated numbers hide a wealth of interesting variation we wish to explore. Recalling equation (1.7), we ask: what is the relationship between transport emission intensity in the base year, and the subsequent growth in trade? In order to explore this relationship we describe the transport emission intensities for an o-d-g trade flow in two ways. First, we separate emission intensities by quartiles and assign each o-d-g observation a dummy variable for the quartile it falls into. We then regress trade growth (by o-d-g) on emissions quartiles (omitting the first, lowest intensity, quartile) and include fixed effects to isolate the source of the variation. We also regress trade growth on determinants of the transport emission intensity including distance, weight/value and the share of air cargo in trade for that o-d-g flow.

The results are in Table 7. On the left is trade growth from the Full Liberalization experiment. We find that higher emission intensity observations have the fastest trade growth. Controlling for origin-industry fixed effects (absorbing differences in rates of protection across industries) this effect is strengthened. Controlling for origin-destination fixed effects the effect is actually reversed. This is because the origin-destination fixed effects control for the distance bias in the original rates of protection; apart from this effect trade grows fastest in the least emission intensive trade flows. This point shows up again in the bottom panel of Table 7 – the strongest determinant of trade growth is the distance between partners. The right side of Table 7 reports the GDP growth experiment. Here we see that the most emissions intensive trade flows grow fastest in all specifications.

We repeat these experiments in Table 8, but this time focused on output emissions in an origin o-industry g pair. We see a different story. In the full liberalization experiment, trade grows slowest for the most emission intensive industries. This is broadly consistent with our aggregate results showing that this scenario led to rising transport emissions but falling output emissions.

V. Conclusions and Implications

Most of the work on trade and climate change has ignored international transportation, or considered it in the context of case studies. This neglect is due in part to a lack of data, and in part to the belief that international transportation represents a small portion of overall emissions.

In this paper we combined data on trade, transportation modes, transport emissions, and output emissions to calculate the contribution of transportation to trade-related greenhouse-gas emissions. While international transportation is a small fraction of overall emissions it is a surprisingly large fraction of trade-related emissions. Two-thirds of trade-related emissions in North American exports are due to international transportation. Nearly 90 percent of trade related emissions in machinery exports are due to international transportation. Further, transport emissions are far more variable than are output emissions. When we combine transport and output emissions together, there is much more variation in emissions across destinations for a given country and industry then there is within an industry across country.

We see several implications of these numbers. One, a change in the partner composition of trade can have a much larger impact on overall emissions than changing what is produced or who produces it. Two, both production and transportation emissions should be considered when evaluating policy changes designed to curtail emissions. In some countries the impact will be felt most acutely on the production side, whereas in other countries the main effect will primarily be on transport. Countries that look to have relatively low emissions when we focus only on output may have relatively high emissions once international transport is factored in.

This point is especially relevant because the international transport sector lies largely outside the usual negotiating framework for emissions. There is no agreement on whether emissions from international transport “belong” to the exporter, to the importer, or are in some sense a country unto themselves. Were transport emissions trivial in magnitude this would be of little concern. They are clearly not.

We then combined these data with simulated trade growth in a number of tariff liberalization and GDP growth experiments. Tariff liberalization leads to emissions growth twice as rapid as trade growth, as trade shifts toward distant partners and more intensive use of air cargo. Transport relative to output emissions in a dollar of exports rise. We also find that trade, transport and emissions growth from GDP growth swamps any changes from tariff liberalization, yielding emissions growth rising at 3-4 percent a year. This numbers suggest that concerns about emissions growth from tariff liberalization are trivial relative to those resulting from output growth, and that likely patterns of trade growth will further emphasize transport emissions relative to output emissions.

It is important to recall that the trade and emissions growth experiments deliberately abstract from important substitution margins. The experiments assume away changes in modal usage within a particular trade flow over time. Similarly, the exercise does not allow for technological change in emission intensities due either to innovation or to updating the vintage of the transportation fleet capital stock. The key point in both instances is that we do not model how changes in fuel prices, spurred either by rising demand for fuel or changes in carbon/fuel taxes, affect mode-specific prices or demand.

Fully modeling the endogenous choice of transportation mode, and the endogenous choice of the vintage of the transportation capital stock was beyond the scope of the current study. However, it could be extremely useful for understanding interactions between trade, transportation and emissions. In particular, it would be interesting to understand how trade liberalization affects relative prices of transport modes through shocks to transport inputs or through the realization of economies or diseconomies of scale. Similarly, the much higher fuel intensity of air cargo, and its associated CO2 emissions, suggests that climate mitigation policies such as a carbon tax could have pronounced effects on how goods move and the kinds of goods that nations trade. This is especially important for countries like the US, whose reliance on air cargo results in unusually high transportation emissions.

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Figure 1: Distribution of Emission Intensities

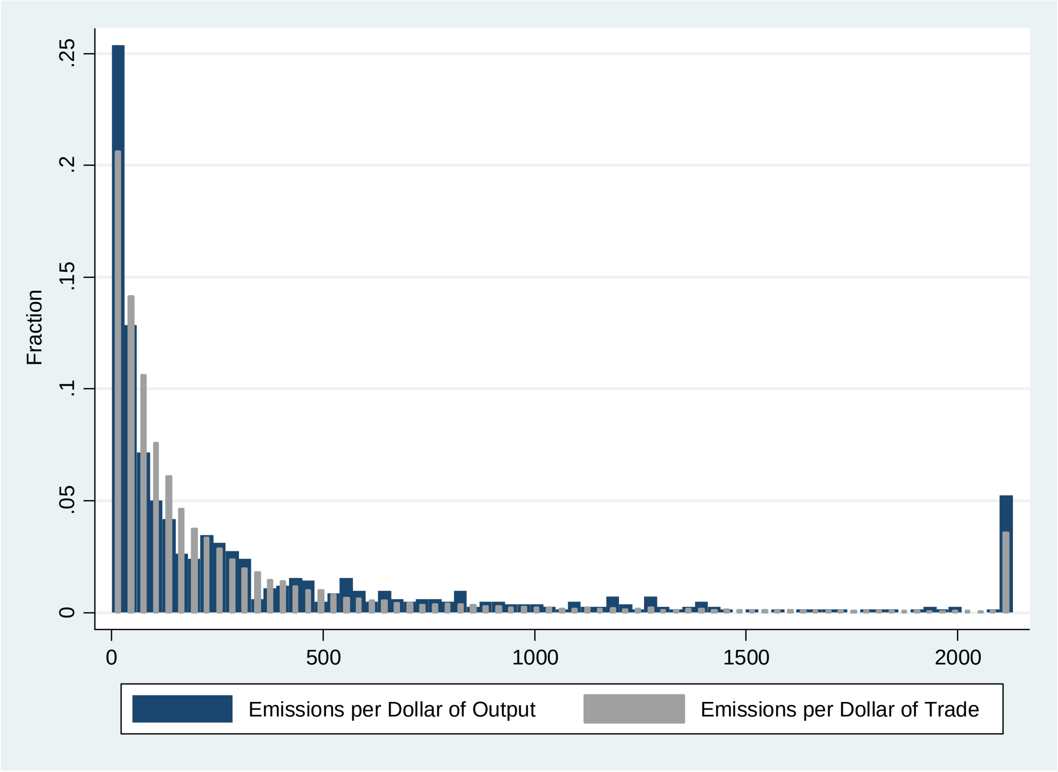

Figure 2: Comparing Transport and Output Emission Intensities

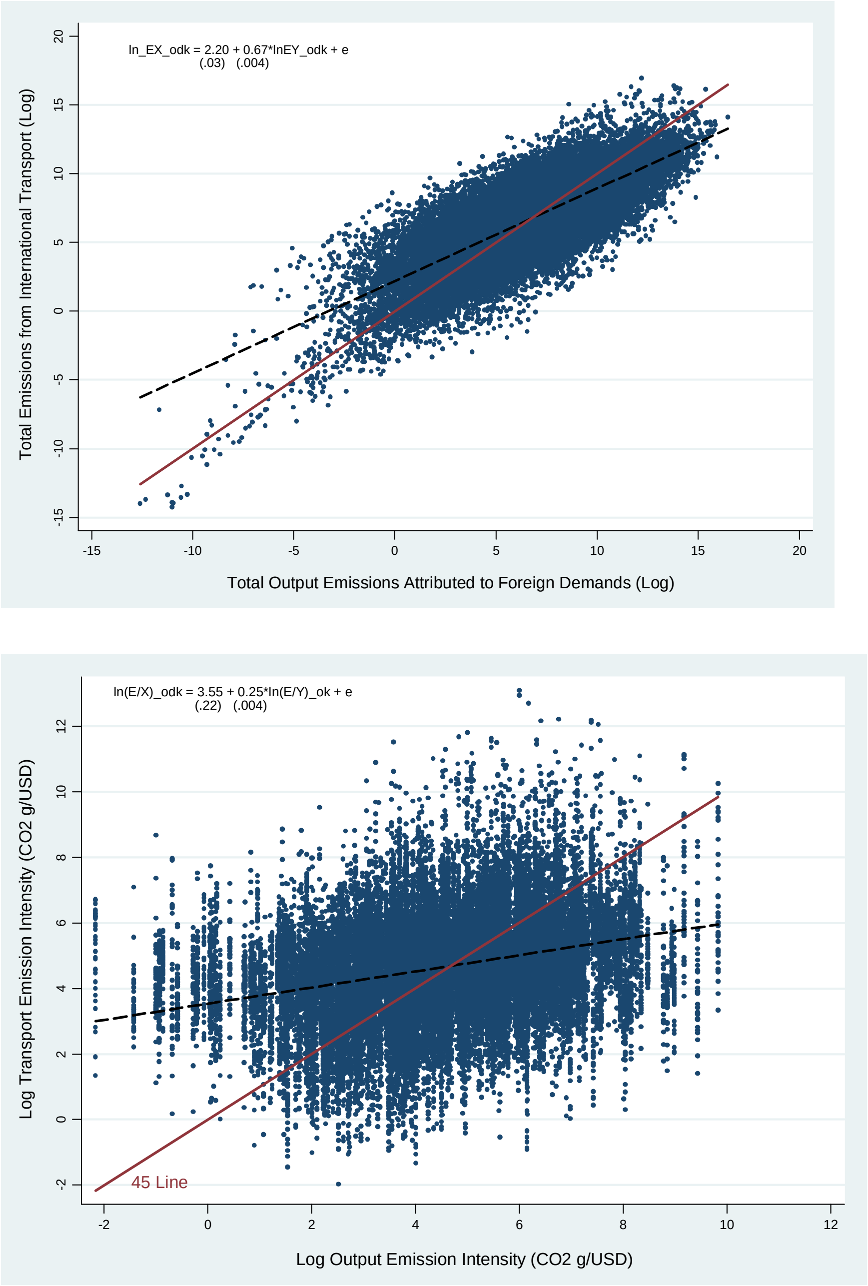

Figure 3: The Contribution of Transport to Total Trade-Related Emissions

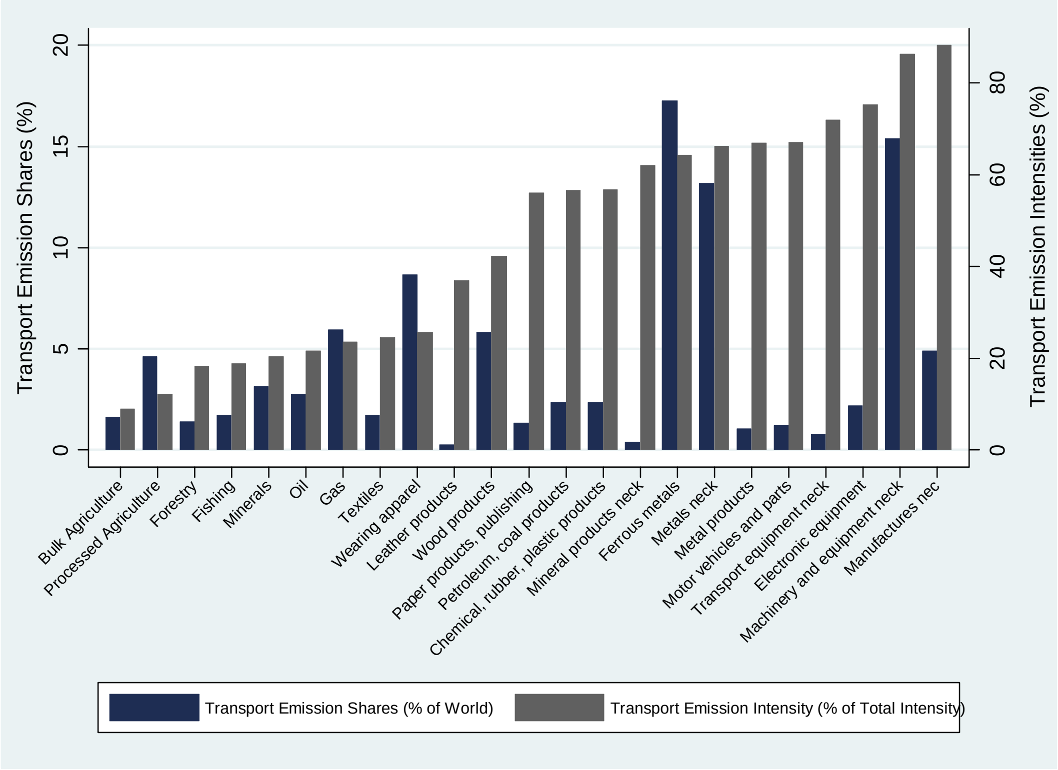

Table 1. World Output and Transport Emissions, 1990-2005 (selected years)

	1990	**1995**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
PANEL A: ECONOMIC INDICATORS								
World Development Indicators								
Exports (billion const 2000 USD)[1]	4088.22	5482.53	7974.08	8026.52	8340.16	8784.89	**9755.42**	10532.83
GDP (billion const 2000 USD)	24279.62	27238.21	32209.31	32725.52	33365.57	34256.90	**35655.09**	36929.93
CO2 Emissions (ITF, IEA)								
CO2 from fuel combustion (mil t CO2)	21024.43	21807.8	23487.23	23599.03	24075.57	25090.14	**26319.92**	27136.36
Industry CO2 (mil t CO2)[2]	4204.89	4361.56	4697.45	4719.81	4815.11	5018.03	**5263.98**	5427.27
Total Transport CO2 (mil t CO2)	4614.07	5046.63	5677.52	5697.57	5815.29	5947.01	**6202.39**	6337.02
International Transport CO2 (mil t CO2)[3]	649.41	710.48	829.4	796.11	816.68	831.72	**910.01**	959.08
PANEL B: INTERNATIONAL TRANSPORT EMISSIONS								
% of total emissions	3.09%	3.26%	3.53%	3.37%	3.39%	3.31%	**3.46%**	3.53%
% of transport emissions	*14.07%*	*14.08%*	*14.61%*	*13.97%*	*14.04%*	*13.99%*	***14.67%***	*15.13%*
% of industry emissions	15.44%	16.29%	17.66%	16.87%	16.96%	16.57%	**17.29%**	17.67%
Industry Emissions per Dollar of Output (CO2 g/$)	173.19	160.13	145.84	144.22	144.31	146.48	**147.64**	146.96
Internat'l Transport Emissions per Dollar of Exports (CO2 g/$)	158.85	129.59	104.01	99.18	97.92	94.68	**93.28**	91.06
Total Emissions per Dollar (Output + International Transport)	332.03	289.72	249.85	243.41	242.24	241.16	**240.92**	238.02
Transport Emission per Dollar (% of total emission per dollar)	47.84	44.73	41.63	40.75	40.42	39.26	**38.72**	38.26

Notes:

[1] WDI world exports values include all sectors (goods + services).

[2] Computed as 20% of total fuel emissions (source: IEA). This is a conservative calculation, since several industries are omitted from the 20% estimate (e.g., commercial/public services, agriculture, forestry, fishing, energy industries).

[3] Includes international maritime and aviation transport modes (source: ITF)

Table 2. Regional Modal Shares, by trade value and KG-KM

Panel (A) Modal shares by importer

	By Value				**By KG-KM**			
	Sea	Air	Rail	Road	Sea	Air	Rail	Road
North America	46.84	20.96	6.49	25.71	90.96	1.19	1.57	6.28
Central America	81.98	13.55	0.14	4.33	98.42	0.58	0.08	0.91
South America	67.17	21.95	0.14	10.74	91.17	1.14	0.10	3.89
Europe	35.09	13.22	4.85	46.65	90.34	1.68	2.60	5.33
South Asia	73.86	22.67	0.60	2.86	98.76	0.80	0.08	0.36
Asia	72.12	26.45	0.22	1.20	98.46	1.40	0.01	0.13
Middle East/Africa	67.95	19.31	0.00	12.74	85.48	1.09	0.00	13.42
Oceania	76.80	23.20	0.00	0.00	97.71	2.29	0.00	0.00
WORLD	49.96	18.60	3.63	27.72	94.13	1.39	0.93	3.43

Panel (B) Modal shares by exporter

	By Value				**By KG-KM**			
	Sea	Air	Rail	Road	Sea	Air	Rail	Road
North America	28.32	26.09	9.18	36.42	87.74	4.65	1.51	6.07
Central America	74.97	19.97	0.19	4.87	97.66	1.00	0.12	1.18
South America	84.75	8.31	0.09	6.85	98.79	0.29	0.02	0.74
Europe	34.58	13.29	4.89	47.04	84.85	1.35	4.51	9.26
South Asia	72.97	22.52	0.78	3.71	97.11	1.21	0.27	1.26
Asia	72.14	26.71	0.18	0.98	98.24	1.29	0.03	0.40
Middle East/Africa	79.98	9.89	0.00	10.13	96.68	0.08	0.00	2.93
Oceania	88.40	11.60	0.00	0.00	99.85	0.14	0.00	0.00
WORLD	49.96	18.60	3.63	27.72	94.13	1.39	0.93	3.43

Table 3. Sectoral Modal Shares, by trade value and KG-KM

Commodity	**By Value**				**By KG-KM**			
	Sea	Air	Rail	Road	Sea	Air	Rail	Road
Bulk Agriculture	77.19	2.76	2.99	17.01	97.21	0.30	1.31	1.18
Processed Agriculture	56.44	2.84	1.89	38.68	91.39	0.65	0.87	7.09
Forestry	67.37	2.18	9.04	21.29	92.29	0.52	3.99	3.19
Fishing	40.38	27.15	0.39	32.04	54.06	33.78	0.18	11.90
Minerals	70.79	21.26	2.96	4.96	98.35	0.07	0.72	0.85
Oil	95.56	0.00	1.19	3.25	97.44	0.00	0.41	1.75
Gas	61.27	0.00	13.98	24.74	93.19	0.00	2.69	3.89
Textiles	57.52	9.72	0.66	32.05	77.42	6.40	0.14	16.04
Wearing apparel	51.77	18.92	0.58	28.68	71.39	20.56	0.12	7.90
Leather products	56.88	14.55	0.35	28.18	81.90	8.76	0.10	9.21
Wood products	50.67	2.27	7.75	39.22	86.17	0.65	2.91	10.26
Paper products, publishing	46.66	5.47	6.41	41.38	87.60	1.57	1.47	9.35
Petroleum, coal products	88.87	0.29	2.61	7.88	96.40	0.21	0.81	2.55
Chemical, rubber, plastic products	46.62	15.88	2.43	34.97	90.55	1.22	1.34	6.89
Mineral products nec	48.93	8.02	2.32	40.60	88.55	1.01	1.59	8.85
Ferrous metals	64.67	1.52	7.01	26.53	93.25	0.30	2.01	4.43
Metals nec	56.28	14.49	3.11	26.03	93.25	1.46	0.75	4.53
Metal products	43.12	10.46	2.00	44.35	75.20	8.21	0.51	16.08
Motor vehicles and parts	44.39	3.37	14.10	37.98	80.22	3.83	3.88	11.44
Transport equipment nec	33.34	43.92	3.46	19.21	84.93	10.91	0.71	2.98
Electronic equipment	33.30	50.12	0.52	16.01	60.51	35.50	0.07	3.51
Machinery and equipment nec	40.52	26.71	2.47	30.26	78.75	13.70	0.44	7.11
Manufactures nec	37.50	41.75	0.54	20.17	86.06	10.21	0.15	3.58
TOTAL	49.96	18.60	3.63	27.72	94.13	1.39	0.93	3.43

Table 4. Emission Shares and Emission Intensities for Transport and Output by Region

	Emission Shares (% of World)			***Emission Intensities (CO2 g/$)***				***Transport Emission Intensities (% of total emissions per USD[2])***	
	Transport ("HIGH" scenario[1])		Output	Transport ("HIGH" scenario)		Output	Output	Transport ("HIGH" scenario)	
	Importer	*Exporter*		*Importer*	*Exporter*	Trade weights	Output weights	*Importer*	*Exporter*
North America	20.69	44.41	15.92	140.81	444.66	238.02	239.76	37.17	65.13
Central America	0.75	0.78	0.86	119.17	80.32	149.45	275.10	44.36	34.96
South America	2.85	5.81	9.17	230.75	314.18	1023.44	909.81	18.40	23.49
Europe	29.26	18.41	19.64	97.55	56.44	137.41	163.15	41.52	29.11
South Asia	2.07	2.97	6.85	173.59	113.47	182.21	770.64	48.79	38.38
Asia	34.95	16.48	31.31	242.04	69.79	159.28	366.65	60.31	30.47
Middle East/Africa	6.92	8.90	14.41	198.25	172.57	660.80	920.99	23.08	20.71
Oceania	2.51	2.24	1.83	271.55	314.01	684.56	446.36	28.40	31.45
WORLD	100	100	100						

Notes:

[1] The "HIGH" scenario uses the higher emissions value per kg-km of cargo moved by air in calculating the total emissions from international transport.

[2] Total emissions per dollar are calculated as the sum of transport and output emission intensites. See equation (1.5) in the text.

Table 5. Worldwide Changes in Output, Trade and Associated Emissions by Scenario

	Doha S04	**Doha S05**	**Doha S09**	**Full Liberalization**	**GDP growth (per annum)**
% Change					
Output	-0.08	-0.06	-0.19	-0.87	3.27
Exports:					
Value	0.04	-0.12	0.90	4.96	3.26
Weight	0.29	-0.07	0.66	6.09	3.17
Kg-Km	0.53	-0.07	1.30	8.14	3.26
CO2 Emissions					
Output	0.12	0.11	0.00	-1.12	4.32
Exports:					
HIGH Scenario	-0.1	-0.25	2.39	10.46	3.39
LOW Scenario	0.0	-0.19	2.01	9.43	3.36

Table 6. Modal Share Growth by Scenario

	Trade Value				**Transportation Services Employed in Trade (KG-KM)**			
	Air	Sea	Rail	Road	Air	Sea	Rail	Road
Doha S04	0.55	-0.32	-0.25	-0.49	0.59	-0.55	-0.19	-0.44
Doha S05	0.04	-0.34	-0.24	-0.27	-0.06	-0.45	-0.54	-0.26
Doha S09	2.71	1.77	-1.23	-1.86	1.38	3.72	-0.49	-1.31
Full Liberalization	12.22	7.57	-2.94	-4.74	8.58	13.99	7.77	-6.18
GDP growth (annualized)	3.65	3.31	2.65	2.37	3.26	3.48	3.07	3.21
GDP growth (Total)	77.56	68.47	52.03	45.39	67.03	72.92	62.34	65.75

Table 7. Regression results: trade value growth and emission intensity

	Dependent Variable: Trade Growth					
	Full Liberalization			**GDP growth**		
Panel (A) On quartiles of (transport) emission intensity						
II quartile	0.161***	0.306***	-0.110***	0.142***	0.086***	0.090***
	[0.032]	[0.030]	[0.033]	[0.016]	[0.013]	[0.017]
III quartile	0.121***	0.435***	-0.211***	0.160***	0.111***	0.130***
	[0.033]	[0.031]	[0.034]	[0.016]	[0.014]	[0.018]
IV quartile	-0.057	0.496***	-0.392***	0.254***	0.162***	0.234***
	[0.035]	[0.036]	[0.036]	[0.017]	[0.016]	[0.019]
Constant	2.837***	2.572***	3.086***	4.003***	4.051***	4.028***
	[0.025]	[0.235]	[0.026]	[0.018]	[0.010]	[0.012]
Fixed Effects		origin-sector	origin-destination		origin-sector	origin-destination
N	20560	20560	20560	31641	31641	31641
R2	0.003	0.012	0.007	0.0074	0.0074	0.0071
Panel (B) On (transport) emission intensity determinants						
Distance	0.443***			0.163***		
	[0.017]			[0.007]		
Weight/Value	-0.144***			0.045***		
	[0.008]			[0.004]		
air use	0.015***			-0.005*		
	[0.005]			[0.003]		
Constant	-1.128***			2.673***		
	[0.165]			[0.067]		
N	18730			27815		
R2	0.0829			0.0304		

*Robust standard errors in parentheses. In panel (A) quartiles are based on the distribution of (log) emission intensity. A trade flow's emission intensity is calculated using the HIGH scenario emissions content.

Table 8. Regression results: Output growth and emission intensity

	Dependent Variable: Output Growth					
	Full Liberalization			**GDP growth**		
On quartiles of (transport) emission intensity						
II quartile	-0.029	-0.093*	-0.002	0.024	-0.008	0.045
	(0.039)	(0.051)	(0.023)	(0.018)	(0.014)	(0.028)
III quartile	0.007	-0.065	-0.026	0.042**	0.022*	0.068**
	(0.024)	(0.047)	(0.031)	(0.018)	(0.013)	(0.031)
IV quartile	-0.259***	-0.380***	-0.048	0.046**	-0.028	0.131***
	(0.0850	(0.121)	(0.045)	(0.022)	(0.021)	(0.032)
Constant	-0.060***	0.004	-0.111***	0.453***	0.485***	0.420***
	(0.011)	(0.047)	(0.023)	(0.013)	(0.009)	(0.019)
Fixed Effects		origin	industry		origin	industry
N	917	917	917	917	917	917
R2	0.023	0.035	0.001	0.007	0.013	0.030

*Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Quartiles are based on the distribution of (log) emission intensity of output. Total emissions per dollar value of output include both CO2 and non-CO2 emissions.

Appendix I GTAP Model Aggregation and Scenarios

Table A.1. Country Aggregation: 40 regions are in bold, with constituent countries listed in parentheses

Austria, Belgium (Belgium, Luxembourg**), Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom, Rest of European Union** (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia (EU 10); Bulgaria, Romania)**, Rest of European Countries** (Switzerland, Rest of EFTA (Iceland, Liechtenstein, Norway), **Other CEE and Other CIS** (Albania, Croatia, Turkey, Rest of Europe (Andorra, Bosnia and Herzegovina, Faroe Islands, Gibraltar, Macedonia, Monaco, San Marino, Serbia and Montenegro), Rest of Former Soviet Union (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova (Republic of), Tajikistan, Turkmenistan, Ukraine, Uzbekistan)**, Russia**

Canada, Unites States, Mexico

Japan, Korea, Singapore, Malaysia-Indonesia, China-Hong Hong, Taiwan, East Asia (Democratic People's Republic of Korea, Macau, Mongolia), **Rest of South Asia** (Bangladesh, Sri Lanka, Afghanistan, Bhutan, Maldives, Nepal, Pakistan)**, Rest of South East Asia** (Philippines, Thailand, Vietnam, Rest of Southeast Asia (Brunei Darussalam, Cambodia, Lao People's Democratic Republic, Myanmar, Timor Leste)**, India**

Oceania Countries (Australia, New Zealand, American Samoa, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Micronesia (Federal States of), Nauru, New Caledonia, Norfolk Island, Northern Mariana Islands, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna)

Argentina, Brazil, Chile, Rest of South America (Colombia, Peru, Uruguay, Venezuela, Bolivia, Ecuador, Falkland Islands, French Guiana, Guyana, Paraguay, Suriname)

Central and Caribbean America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Anguilla, Aruba, Cayman Islands, Cuba, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, Turks and Caicos, British Virgin Islands, Antigua and Barbuda, Bahamas, Barbados, Dominica, Dominican Republic, Grenada, Haiti, Jamaica, Puerto Rico, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago, U.S. Virgin Islands, Bermuda, Greenland, Saint Pierre and Miquelon)

Middle East and North Africa (Morocco, Tunisia, Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Palestinian Territory, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen, Algeria, Egypt, Libyan Arab Jamahiriya) **South Africa, Sub-Saharan Africa** (Botswana, Madagascar, Malawi, Mozambique, Tanzania, Uganda, Zambia, Zimbabwe, Lesotho, Namibia, Swaziland, Angola, Congo (the Democratic Republic of the), Mauritius, Seychelles, Benin, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Mali, Mauritania, Mayotte, Niger, Nigeria, Reunion, Rwanda, Saint Helena, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, Sudan, Togo)

Table A2. Sectoral Aggregation.

27 Sectors in bold, aggregation of constituent 57 GTAP sectors listed in parentheses)

Bulk Agriculture (Paddy rice; Wheat; Cereal grains nec; Oil seeds; Sugar cane, sugar beet; Plant-based fibers; Crops nec);

Processed Agriculture (Vegetables, fruit, nuts; Bovine cattle, sheep and goats, horses; Animal products nec; Raw milk; Wool, silk-worm cocoons; Bovine meat products; Meat products nec; Vegetable oils and fats; Dairy products; Processed rice; Sugar; Food products nec; Beverages and tobacco products

Forestry, Fishing, Minerals (Coal, Mineral nec, Oil, Gas)

Textiles, Wearing apparel, Leather products, Wood products, Paper products and publishing

Petroleum and coal products; Chemical and rubber and plastic products, Mineral products nec, Ferrous metals, Metals nec, Metal products

Motor vehicles and parts, Transport equipment nec, Electronic equipment, Machinery and equipment nec, Manufactures nec

Electricity, Gas manufacture and distribution

Services: (Water; Construction; Trade; Communication; Financial services nec; Insurance; Business services nec; Recreational and other services; Public Administration, Defense, Education, Health; Dwellings)

Transport nec, Water transport, Air transport

Appendix 3. Sources of Modal Data and Calculation of Modal Shares

TO → FROM ↓	**US**	**EU15**	**EU10**	**Romania and Bulgaria**	**LAC**	**ROW**
US	--	*European Import or US Export Data*	*European Import or US Export Data*	*European Import or US Export Data*	*US Export or Aladi Import data*	*US Export data*
EU15	*European Export or US Import Data*	*European Export data (1999)**	*European Export data (1999)**	*European Export data*	*European Export data*	*European Export data*
EU10	*European Export or US Import Data*	*European Import Data*	*European Import Data*	*European Import Data*	*European Export data*	*European Export data*
Romania and Bulgaria	*European Export or US Import Data*	*European Import Data*	*European Import Data*	*European Import Data*	*European Export data*	*European Export data*
LAC	*US Import Data*	*European Import Data*	*European Import Data*	*European Import Data*	--	--
ROW	*US Import Data*	*European Import Data*	*European Import Data*	*European Import Data*	--	--

*Year 1999 is the base for data in both the 2000 and the 2004 datasets.

Modal usage is central to this exercise it is necessary to estimate modal shares for the roughly one-third of world trade where no direct information on modal use is available. In these cases we estimate modal use by relying on the matrix of modal trade flows we do have and the following three step algorithm.

1. Estimate the share of trade that moves by land.

If an o-d country pair is not on the same continent, or a destination could not reasonably be reached by land transport, rail and road shares are set to zero. (That is, Japan is part of Asia, but lacks a land bridge so its rail and road shares are zero.)

For European country pairs not covered explicitly by the EU data, we estimate a modal share model with first the rail share of trade and then the road share as a dependent variable. Regressors include fixed effects for origin, destination, and GTAP sector, the distance between countries, a dummy for land-adjacency, and the weight/value ratio of the exporter-sector. The sample employed is the EU data for which we do have modal information – recall that all the EU 27 countries report their imports from all European countries and their exports to all European countries. We then use out of sample prediction to generate modal splits for the remaining countries. This allows us to estimate, for example, the share of rail in Russian exports of coal by calculating Russia's conditional average share of rail to the EU27 countries (the origin fixed effect), the weight/value of Russian coal, and the distance to each market.

This leaves intra-continental trade within Africa and land-adjacent Asian countries, roughly 1.8 percent of world trade by value. For Asia we use calculations by Prabir De (2007) that report the modal shares of Indian trade with its land-adjacent neighbors, summed over all products and partners. These shares do not vary over sectors. For intra-African trade (a vanishingly small share of world trade) we could find no data on modal shares and so imposed road shares of 75 percent and rail shares of 0.

2. Calculate the share of trade that moves via ocean or air as the residual of 1 – rail share – road share.

3. Split the (air+ocean) share

We estimate a model where the dependent variable is the ratio of air/ocean and the regressors include the weight/value ratio of the exporter-product, distance between markets, whether they are land-adjacent and vectors of fixed effects by origin, destination, and GTAP sector. These origin and destination fixed effects capture all market characteristics such as level of development, and quality and composition of infrastructure that strongly affect this modal split. The product fixed effects absorb factors that explain modal use such as bulk, spoilage, the need for special packing, and timely delivery. Again, the estimation sample includes the EU, US, and ALADI data for which we have explicit modal share data and we use out of sample prediction to generate modal splits for the remaining countries. The high R2 in these regressions (.75) suggests that the model does a good job of identifying share variation.

Appendix Table A3. Projected GDP Growth

Country/Region	GDP in 2004 (million USD)	Projected GDP growth, %
United States	11,673,381	66.77
European Union	679,989	73.57
Brazil	616,540	76.37
Canada	979,128	51.08
Japan	4,658,738	30.59
China and Hong Kong	1,837,133	174.2
India	641,258	139.09
Central and Caribbean Americas	287,055	69.89
South and Other Americas	338,707	62.85
East Asia	25,587	63.62
Malaysia and Indonesia	369,601	130.48
Rest of South East Asia	309,856	92.73
Rest of South Asia	184,630	120.11
Russia	569,838	67.56
Other East Europe	552,560	89.15
Rest of European Countries	623,307	39.93
Middle Eastern and North Africa	1,116,390	88.97
Sub Saharan Africa	310,017	77.05
Oceania countries	755,508	72.51
Korea	676,497	109.03
Taiwan	305,291	89.07
Singapore	106,814	116.45
Mexico	683,236	81.48
Argentina	150,397	73.28
Chile	89,640	96.46
Austria	292,312	47.64
Belgium	384,176	41.8
Denmark	243,730	41.03
Finland	185,920	60.24
France	2,046,465	44.14
Germany	2,740,501	33.28
United Kingdom	2,123,599	41.87
Greece	205,197	47.34
Ireland	182,242	102.25
Italy	1,677,820	41.61
Netherlands	578,980	51.5
Portugal	167,715	47.22
Spain	1,039,899	56.6
Sweden	346,413	49.02
South Africa	213,934	69.02
WORLD	40,970,001	65.83

Appendix Table A4. Baseline Descriptives by Commodity

Commodity	**Tariff**	**Weight/Value**	**Share of:**		
			World Output	Trade Value	Kg-Km
Bulk Agriculture	8.98	3.09	0.98	1.16	5.28
Processed Agriculture	9.68	0.95	6.39	5.50	5.30
Forestry	1.13	7.13	0.21	0.13	0.82
Fishing	3.37	0.25	0.20	0.14	0.02
Minerals	1.56	14.09	0.63	1.32	26.98
Oil	1.22	4.57	1.11	4.82	25.00
Gas	0.09	5.26	0.24	0.71	2.52
Textiles	6.91	0.32	1.12	2.63	0.76
Wearing apparel	7.69	0.06	0.84	1.94	0.13
Leather products	7.37	0.17	0.32	1.02	0.21
Wood products	1.66	1.00	0.92	1.67	1.18
Paper products, publishing	1.64	1.15	1.97	1.92	1.85
Petroleum, coal products	3.25	4.34	1.84	2.00	7.38
Chemical, rubber, plastic products	2.57	0.77	4.77	11.69	8.21
Mineral products nec	3.71	1.98	1.04	1.06	1.71
Ferrous metals	2.46	1.98	1.44	2.48	4.15
Metals nec	2.11	0.51	0.84	2.46	1.34
Metal products	3.03	0.77	1.64	1.92	1.33
Motor vehicles and parts	3.45	0.17	3.05	8.62	1.04
Transport equipment nec	2.01	0.08	0.85	2.55	0.26
Electronic equipment	1.14	0.07	3.04	10.98	1.09
Machinery and equipment nec	2.58	0.20	4.55	13.70	3.00
Manufactures nec	2.57	0.16	1.03	1.81	0.34
Electricity	0.16		1.80	0.27	
Gas manufacture, distribution	0.00		0.22	0.06	
Services	0.00		54.02	13.11	
Transport nec	0.00		3.54	1.96	
Water transport	0.00		0.65	0.75	
Air transport	0.00		0.75	1.62	
TOTAL	2.64	0.92	100.00	100.00	99.91