Online Appendix for 'Trade and the Greenhouse Gas Emissions from International Freight Transport', Cristea Anca, David Hummels, Laura Puzzello and Avetisyan Misak: Supplementary Materials

The supplementary materials consist of Appendix SM1, Appendix SM2, and three tables, Tables SM1-SM3. Appendix SM1 discusses the source of modal data and the methodology we adopted for the calculation of modal shares. Appendix SM2 provides the policy details underlying the tariff liberalization simulations whose results we discuss in section VI of our paper. Table SM1 provides modal shares for each traded sector, by trade value and kg-km. Table SM2 reports the fraction of trade reallocations that are GHG emission reducing for each country and producing sector. Table SM3 summarizes the rates of real GDP and factor input growth underlying the GDP growth simulation whose results we discuss in section VI of our paper.

Appendix SM1: Sources of Modal Data and Calculation of Modal Shares

The table below summarizes the source of modal data for worldwide trade flows. X indicates that modal shares are directly observed from various data sources, as follows. These data represent 65% of the value of world trade.

X^a Modal shares calculated using Eurostats data on European exports. For flows from EU15 to EU25 (excluding Bulgaria and Romania), modal shares are originally reported at the 3 digit level of the NSTR. These data were compiled on special request by statisticians at Eurostats. We apply the most recently available year, 1999.

X^b. Modal shares calculated from Eurostats data on European imports.

X^c. Modal shares calculated using US "Imports of Merchandise", US Bureau of the Census.

X^d. Modals shares calculated from ALADI trade data.

X^e. Modal shares calculated using US "Exports of Merchandise", US Bureau of the Census.

X^f. Modal shares calculated using US "Exports and Imports of Merchandise" (US Bureau of the Census) and freight flows data from the North American Transborder Freight Data.

The remaining values are estimated. A/O indicates that land transport is not available between regions, and so trade flows are split between air and ocean. L/A/O indicates that land (rail, truck), air, and ocean shares are imputed.

Importer / Exporter	EU	US	LAC	Rest of Europe	Canada, Mexico	Asia	Africa	Other
EU	X[a]	X[a]	X[d]	X[a]	X[a]	X[a]	X[a]	X[a]
US	X[b]	--	X[d]	X[e]	X[f]	X[e]	X[e]	X[e]
LAC	X[b]	X[c]	X[d]	A/O	A/O	A/O	A/O	A/O
Rest of Europe	X[b]	X[c]	X[d]	L/A/O	A/O	A/O	A/O	A/O
Canada, Mexico	X[b]	X[f]	X[d]	A/O	L/A/O	A/O	A/O	A/O
Asia	X[b]	X[c]	X[d]	A/O	A/O	L/A/O	A/O	A/O
Africa	X[b]	X[c]	X[d]	A/O	A/O	A/O	L/A/O	A/O
Other	X[b]	X[c]	X[d]	A/O	A/O	A/O	A/O	A/O

Modal Share Data Imputation: For trade flows representing 35 percent of world trade, 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 four-step algorithm.

1. Identify trade where land transport is infeasible.

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.). Of the 35 percent of world trade not covered by our explicit modal share data, 33 percent have no land-based trade. For these cases, skip to step three.

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

For the 2 percent of world trade without modal data, and where land transport is an option, we proceed on a case by case basis. 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.

3. Split the (air+ocean) share

Recall that in almost all cases (33 percent of the 35 percent of trade with no data), the ocean + air share is 100%. In the remaining 2 percent of cases we split air v. ocean for the trade that is leftover after subtracting off the shares of trade going to rail and road transport. 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 (0.75) suggests that the model does a good job of identifying share variation.

Appendix SM2: Simulating Trade 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 modelled 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 taken from 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.[1] The non-agricultural tariff cuts are non-proportional, so that peak tariffs are reduced more than lower tariffs. Non-linear tariff cuts formulas 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.

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

Table SM1. 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	76.95	3.18	2.87	16.95	97.02	0.35	1.28	1.36
Processed Agriculture	56.42	2.77	1.98	38.68	91.77	0.54	0.84	6.86
Forestry	67.76	2.41	7.88	21.83	92.21	0.52	3.60	3.67
Fishing	41.73	25.78	0.40	32.05	71.02	19.51	0.11	9.36
Minerals	71.70	20.38	2.82	5.07	98.48	0.08	0.65	0.79
Oil	96.45	0.00	1.16	2.39	98.41	0.00	0.31	1.28
Gas	62.12	0.00	13.37	24.50	96.00	0.00	1.10	2.90
Textiles	58.19	9.08	0.61	32.07	80.96	4.82	0.13	14.08
Wearing apparel	52.56	17.93	0.58	28.88	76.03	16.23	0.11	7.63
Leather products	56.85	14.43	0.31	28.37	81.85	8.68	0.12	9.35
Wood products	50.86	2.05	8.75	38.25	87.74	0.47	2.71	9.08
Paper products, publishing	47.01	5.00	5.80	42.11	89.92	0.95	1.57	7.56
Petroleum, coal products	89.07	0.24	2.97	7.37	97.43	0.12	0.68	1.77
Chemical, rubber, plastic products	45.96	16.44	2.42	35.08	91.35	1.11	1.11	6.44
Mineral products nec	49.27	7.94	2.25	40.41	90.66	0.65	1.26	7.43
Ferrous metals	65.15	1.36	7.08	26.14	94.36	0.17	1.66	3.81
Metals nec	57.56	13.23	3.09	26.03	93.93	0.89	0.73	4.45
Metal products	43.65	10.16	2.08	44.03	77.43	7.32	0.41	14.85
Motor vehicles and parts	44.81	3.42	12.95	38.66	81.58	4.34	2.53	11.54
Transport equipment nec	34.04	43.52	3.35	19.03	86.02	9.86	0.92	3.20
Electronic equipment	32.78	50.21	0.58	16.38	68.19	28.61	0.07	3.13
Machinery and equipment nec	41.79	25.34	2.31	30.52	81.66	11.42	0.35	6.57
Manufactures nec	36.45	42.82	0.61	20.07	86.76	8.95	0.16	4.13
TOTAL	50.25	18.36	3.50	27.81	95.05	1.10	0.78	3.06

Table SM2. Fraction of Trade Exchanges that are CO2 Reducing

By Importer	Fraction (%)	By Sector	Fraction (%)
Singapore	0.21	Wood products	5.75
Sweden	2.87	Leather products	12.11
Japan	3.97	Forestry	12.86
Portugal	6.03	Oil	14.55
Mexico	6.43	Metal products	17.26
Germany	8.99	Paper products, publishing	17.62
Rest of European Countries	9.39	Manufactures nec	17.66
Italy	11.33	Wearing apparel	20.03
Denmark	11.40	Petroleum, coal products	20.65
Canada	12.87	Textiles	21.77
France	14.39	Processed Agriculture	24.94
Taiwan	15.18	Transport equipment nec	26.91
Finland	16.29	Machinery and equipment nec	26.98
Oceania countries	16.71	Minerals	27.06
Ireland	17.23	Metals nec	29.61
Brazil	20.82	Motor vehicles and parts	30.66
Korea	21.74	Ferrous metals	32.77
South Africa	22.08	Gas	32.92
Austria	23.39	Bulk Agriculture	34.24
Belgium	25.58	Mineral products nec	34.98
Central and Caribbean Americas	26.05	Fishing	39.95
Netherlands	27.99	Electronic equipment	45.23
United Kingdom	30.22	Chemical, rubber, plastic products	47.39
Spain	33.27		
India	36.50		
United States	36.87		
Greece	40.99		
Rest of South East Asia	43.54		
European Union	44.27		
Malaysia and Indonesia	49.37		
Sub Saharan Africa	49.57		
Argentina	50.02		
Russia	53.78		
South and Other Americas	57.68		
Chile	60.95		
Rest of South Asia	62.78		
China and Hong Kong	69.29		
Middle Eastern and North Africa	78.08		
Other East Europe	78.82		
Rest of East Asia	80.19		
Average	**30.62**	**Average**	**30.62**

Note: Details on the regional and sectoral aggregation are provided in Appendix 1 of our paper.

Table SM3. Projected GDP Growth

Country/Region	GDP in 2004 (billion USD)	Projected Growth, 2004-2020, %			
		GDP	Capital	Unskilled Labor	Skilled Labor
Argentina	150	73.3	48.3	24.5	146.2
Austria	292	47.6	51.0	15.1	3.2
Belgium	384	41.8	58.0	2.6	-8.0
Brazil	617	76.4	68.0	13.1	61.9
Canada	979	51.1	68.1	28.4	15.5
Central America and Caribbean	287	69.9	85.8	33.5	76.4
Chile	90	96.5	128.2	51.6	132.9
China and Hong Kong	1,837	174.2	266.0	14.1	87.1
Denmark	244	41.0	58.1	7.8	-3.3
East Asia	26	63.6	68.3	25.4	35.9
Rest of European Union	680	73.6	73.2	-14.9	-7.8
Finland	186	60.2	50.5	8.7	-2.6
France	2,046	44.1	52.5	16.9	4.8
Germany	2,741	33.3	36.1	8.0	-3.2
Greece	205	47.3	72.8	15.1	3.2
India	641	139.1	161.5	28.3	88.8
Ireland	182	102.3	135.6	46.6	31.4
Italy	1,678	41.6	42.6	-0.7	-10.9
Japan	4,659	30.6	49.3	2.9	-10.5
Korea	676	109.0	118.6	35.8	147.7
Malaysia and Indonesia	370	130.5	127.5	47.2	174.4
Mexico	683	81.5	69.5	51.5	106.7
Middle Eastern and North Africa	1,116	89.0	92.4	34.4	62.5
Netherlands	579	51.5	52.8	16.6	4.6
Oceania countries	756	72.5	83.8	31.5	13.2
Other East Europe	553	89.2	82.3	12.9	41.7
Portugal	168	47.2	77.8	9.4	-1.9
Rest of European Countries	623	39.9	35.9	21.7	9.1
Rest of South Asia	185	120.1	122.8	40.4	79.8
Rest of South East Asia	310	92.7	88.2	21.0	76.1
Russia	570	67.6	73.2	-1.6	6.6
Singapore	107	116.5	131.4	10.5	19.8
South Africa	214	69.0	675.8	26.2	36.7
South and Other Americas	339	62.9	59.9	21.8	81.0
Spain	1,040	56.6	84.0	17.4	5.3
Sub Saharan Africa	310	77.1	85.9	51.6	72.5
Sweden	346	49.0	48.5	14.3	2.4
Taiwan	305	89.1	118.5	1.2	9.7
United Kingdom	2,124	41.9	48.9	17.5	5.3
United States	11,673	66.8	86.8	26.9	14.1
WORLD	40,970	64.6	83.3	18.7	21.8