ONLINE APPENDIX TO
The Long and Short (Run) of Trade Elasticities*

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Appendix A Data

A.1 Data sources and documentation

This appendix documents our data sources.

Tariff data Tariff data come from UN TRAINS, and are downloaded for each year between 1995-2018 from https://wits.worldbank.org. The raw data are at the importer-exporter-HS6 level, and include information on the year of the tariffs, MFN tariff rates, preferential tariff rates (if applicable), MFN bound rates, whether or not specific duties are applied, and the standard deviation of tariffs within the importer-exporter-HS6-year observation. Reported tariff rates are generally available as simple averages and trade-weighted averages.

When cleaning the data, we drop any observations where either the reporting country or partner country is not identified. We further drop observations where any specific tariffs are reported. When the simple average applied tariff is missing and the corresponding MFN rate is 0, we assume the missing applied tariff is 0, as it is unlikely a country which can export at an MFN rate of 0 actually trades at a higher applied tariff. In other instances, we do not replace missing tariff rates with MFN tariff rates even if MFN rates are available. Rather, we drop observations where the relevant tariff rates are missing, and so these are not used in our estimation.

Figure A1 reports the frequency distribution of tariff changes in our final dataset (where the cleaned tariff data is matched to trade flows). The left panels plot the changes including zero changes, highlighting that in most periods tariffs do not change. The right panels plot the distribution of tariff changes excluding zero changes, and illustrate that there is significant variation in our tariff data. Figure A2 reports the unconditional autocorrelation of tariff changes in our data. Tariff changes display a strong negative first order autocorrelation.

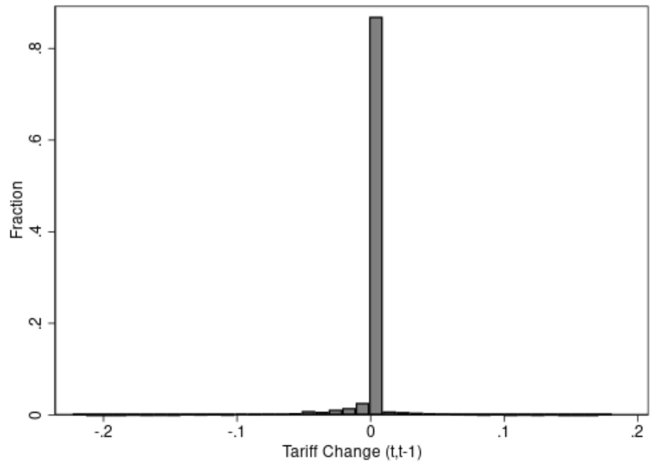
Trade data Trade data are obtained from the BACI version of UN Comtrade. This dataset is produced by the CEPII, and combines importer and exporter reports for more exhaustive and precise coverage of world trade flows. It can be downloaded by registering at the CEPII site `http://www.cepii.fr/CEPII/en/bdd_modele/presentation.asp?id=37`. The most detailed level of disaggregation available is HS6, which is the level of our analysis.

The trade data and tariff data come in several different HS vintages. As discussed in Section II, we do not want to concord HS codes across vintages unless the concordance is one-to-one, to avoid spurious changes in trade flows or tariffs from splitting HS codes or aggregating HS codes across vintages. We therefore only link HS codes across vintages if their mapping is one-to-one. Codes that do not map one-to-one across vintages are kept in the sample, but their time series dimension will be short. Appendix table A1 documents the share of unique HS code mappings across vintages. Figures A3, A4 and A5 document patterns in the trade data. We find that a large share of trade is on an MFN basis, and there is substantial heterogeneity across HS sections (broad groupings of HS codes) in their shares of total trade.

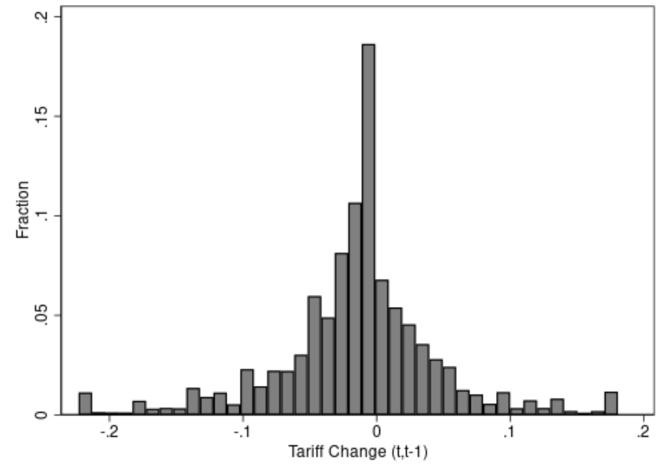
Other data sources While information on ad-valorem tariffs and trade flows at the importer-exporter-HS6-year level are sufficient for the bulk of our analysis, in robustness exercises we use some alternative data sources. Data on temporary trade barriers such as antidumping duties and countervailing duties comes from the database constructed by Bown (2011) and maintained by the World Bank (World Bank, 2021) https://www.worldbank.org/en/data/interactive/2021/03/02/temporary-trade-barriers-database. Standard variables for gravity controls come from the CEPII.

Our dynamic model in Section V.A requires some additional data for calibration. Data on countries' GDP are obtained from the Penn World Tables 9.1 (Feenstra, Inklaar, and Timmer, 2015; Groningen Growth and Development Centre, 2019). Import shares and consumption shares by sector are obtained from the WIOD (Timmer et al., 2015; Groningen Growth and Development Centre, 2016) and World KLEMS data (2017 vintage) (World KLEMS, 2010).

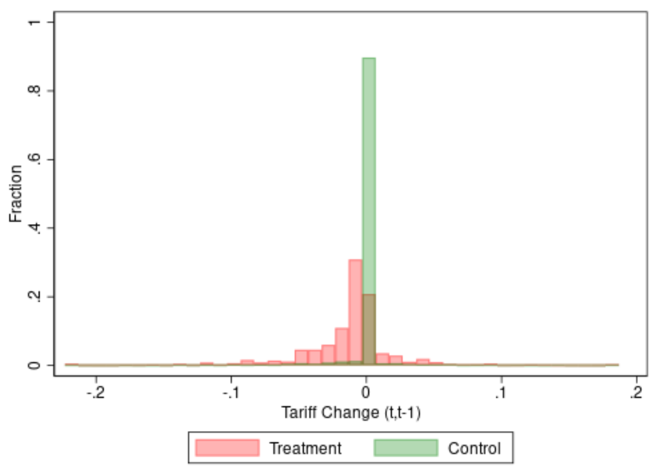
Figure A1: Patterns of Tariff Changes: Frequency Distributions



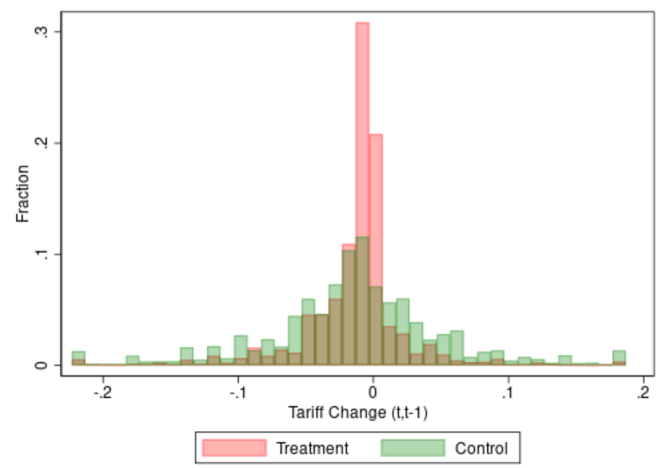
Unconditional



Unconditional, Excluding Zeros



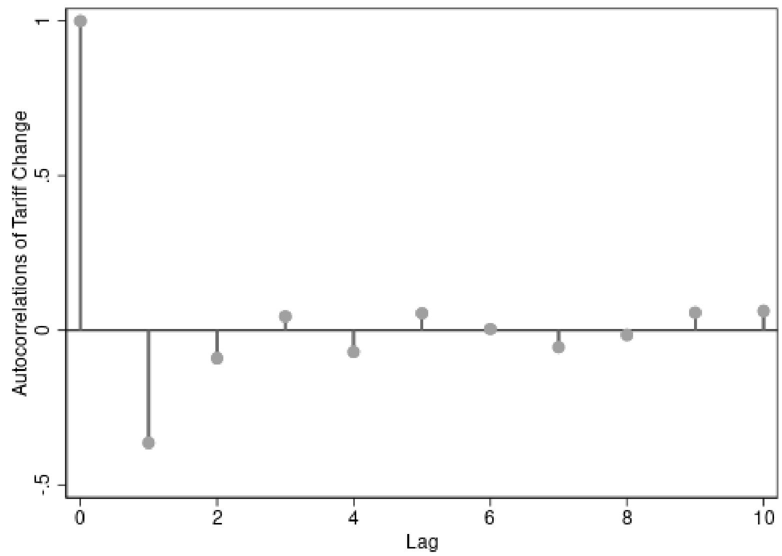
Treatment and Control



Treatment and Control, Excluding Zeros

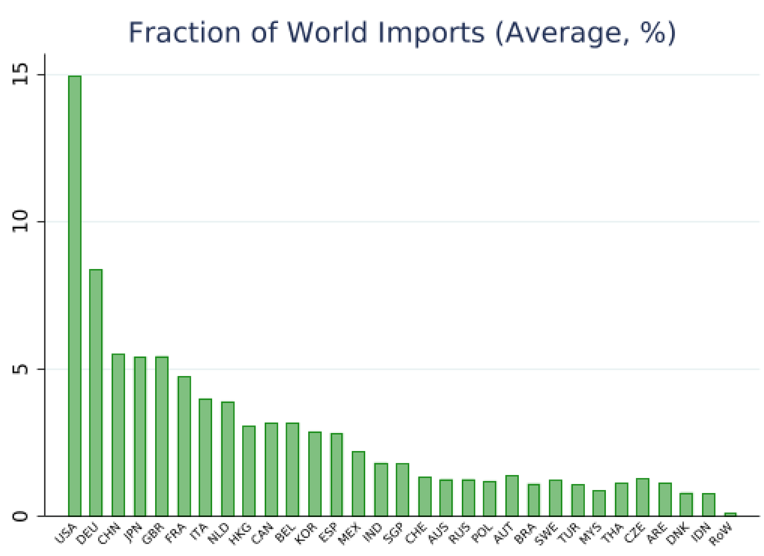
Notes: These figures display the frequency distribution of tariff changes in our data. The top two panels display the unconditional frequency of all tariff changes (top left) and the frequency excluding zeros (top right). The bottom panels displays the frequency distributions of changes in the treatment and control groups, including zero changes (left panel), and removing zero changes (right panel).

FIGURE A2: Patterns of Tariff Changes: Autocorrelation



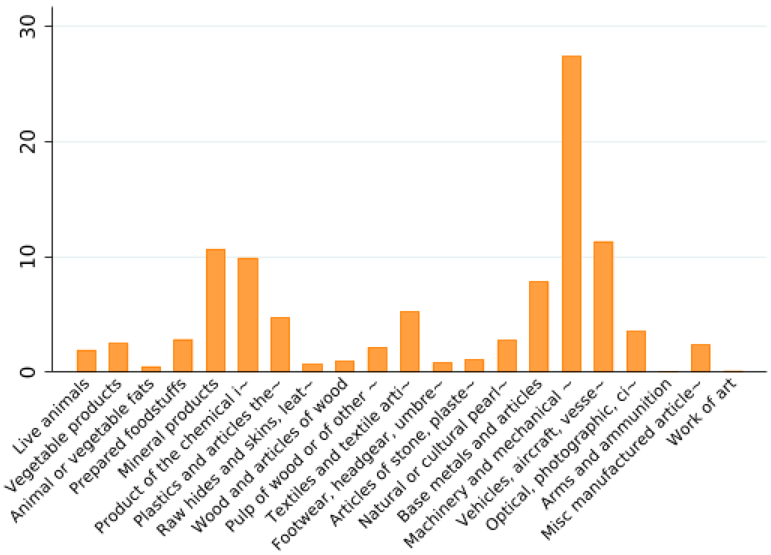
Notes: This figure displays the unconditional autocorrelation of tariff changes in the sample.

FIGURE A3: Share of World Imports by Country (Average, %)



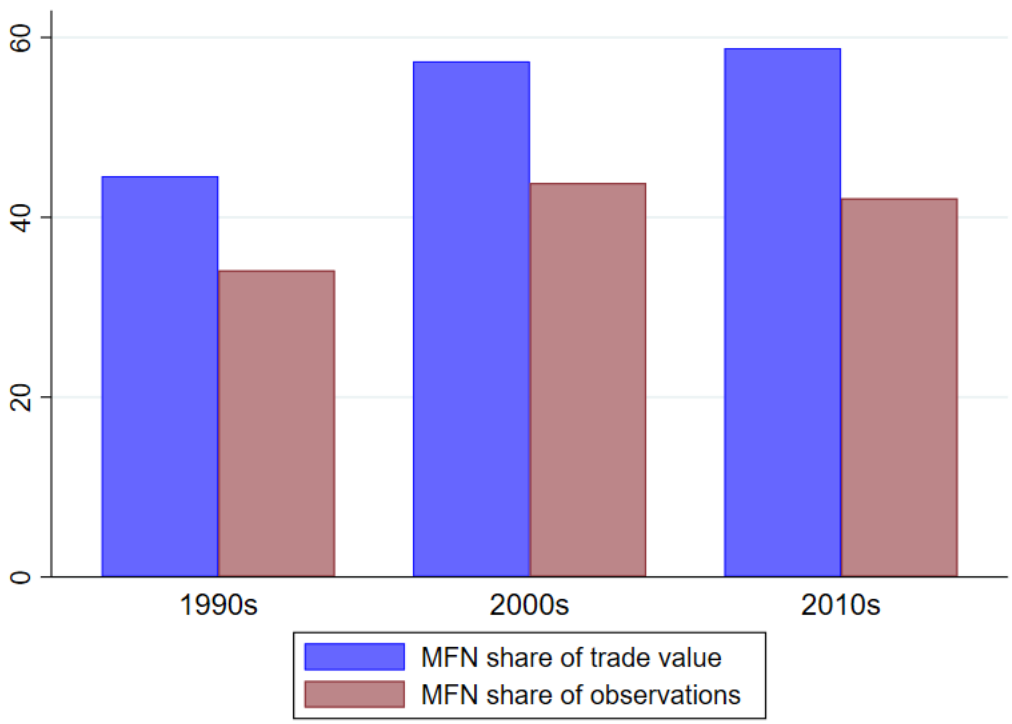
Notes: This figure shows the average share of world trade flows by importer in our sample. "ROW" is the mean share of world trade among countries outside of the top 20 importers.

Figure A4: Share of World Imports by HS Section (Average, %)



Notes: This figure shows the average share of trade that is in each HS Section in our sample.

Figure A5: Share of World Imports on MFN basis (%)



Notes: This figure shows the average share of the value of world trade that is subject to MFN tariffs by decade in our sample and the average share of exporter-importer-HS6-year observations that are trading on MFN terms by decade in our sample. For consistency with our estimation, an observation is treated as MFN only if it is currently trading on MFN terms and was also trading on MFN terms in the previous period.

Table A1: Share of one-to-one Mappings Across HS Revisions (percent)

		Mapped to:				
		HS-92	HS-96	HS-02	HS-07	HS-12
	HS-96	89.38				
	HS-02	81.55	90.81			
Mapped from:	HS-07	73.34	80.74	88.48		
	HS-12	68.17	74.91	81.81	91.93	
	HS-17	61.85	67.92	73.62	81.99	88.05

Notes: This table presents the share of HS codes that can be mapped uniquely from one HS revision (in the "Mapped from" row) to another HS revision (in a "Mapped to" column). All numbers are in percent. Concordances are provided by United Nations Statistics Division (1992-2017).

Table A2: Examples of Treatment and Control Assignments

Importer	MFN Trade Partners		Major Trade Partners Aggregate		Major Trade Partners HS 6403		Treatment	Control	Excluded
	2005	2006	2005	2006	2005	2006			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Germany									
	USA	USA	FRA	FRA	ITA	ITA	HKG	ITA	CHN
	CHN	CHN	BEL	BEL	CHN	CHN	KOR	PRT	IND
	JPN	JPN	NLD	NLD	PRT	PRT	SGP	AUT	USA
	KOR	KOR	ITA	ITA	AUT	AUT	NZL	VNM	
	IND	IND	GBR	GBR	VNM	VNM	CAN	NLD	
	HKG	HKG	CHN	CHN	NLD	NLD	AUS	ESP	
	CAN	CAN	USA	USA	ESP	ESP	JPN	SVK	
	SGP	RUS	AUT	AUT	IND	IND	PRK	FRA	
	BRA	SGP	CZE	CZE	SVK	SVK		IDN	
	RUS	BRA	CHE	CHE	FRA			GBR	
Panel B: Japan									
	CHN	CHN	CHN	CHN	KHM	CHN	BGR	KHM	CHN
	USA	USA	USA	USA	CHN	ITA	GBR	MMR	IDN
	KOR	KOR	AUS	SAU	MMR	KHM	HRV	BGD	VNM
	AUS	AUS	IDN	ARE	BGD	VNM	PRT	MEX	THA
	DEU	DEU	KOR	AUS	IDN	FRA	BIH	LAO	ITA
	ITA	ITA	DEU	IDN	VNM	IDN		NPL	USA
	FRA	FRA	THA	KOR	ITA	MMR		LBN	KOR
	VNM	VNM	MYS	DEU	FRA	ESP			FRA
	GBR	GBR	ARE	THA	ESP	BGD			ESP
	THA	THA	SAU	MYS	DEU	DEU			DEU
Panel C: USA									
	CHN	CHN	CAN	CAN	CHN	CHN	HKG	MEX	CHN
	JPN	JPN	MEX	MEX	ITA	ITA	PRT	CAN	ITA
	DEU	DEU	CHN	CHN	BRA	BRA	DNK	DOM	BRA
	KOR	KOR	JPN	JPN	VNM	VNM	SVK	ISR	VNM
	GBR	GBR	DEU	DEU	MEX	MEX	HUN	COL	THA
	ITA	ITA	GBR	GBR	THA	THA	CHE	SLV	IDN
	FRA	FRA	KOR	KOR	IDN	IDN	AUT	MAR	ESP
	IND	HKG	FRA	VEN	ESP	ESP	ALB	ZAF	IND
	HKG	SWE	ITA	FRA	IND	IND	POL	AUS	FRA
	SWE	IND	MYS	MYS	CAN	CAN	NLD	GTM	DEU

Notes: This table illustrates how partner countries are assigned to treatment group, control group, or excluded from the analysis, using as an example product code 6403 "Footwear; with outer soles of rubber, plastics, leather or composition leather and uppers of leather" in 2006. Columns 1-2 list the top exporters to three importing countries – USA, Germany and Japan – exporting under the MFN regime in periods $t = 2006$ and $t - 1 = 2005$. Columns 3-4 list the importing countries' major aggregate trading partners in these periods. Columns 5-6 list the major trading partners in product 6403. Columns 7-9 then list the main countries in the treatment, control and excluded group for imports of product 6403 to the three importing countries.

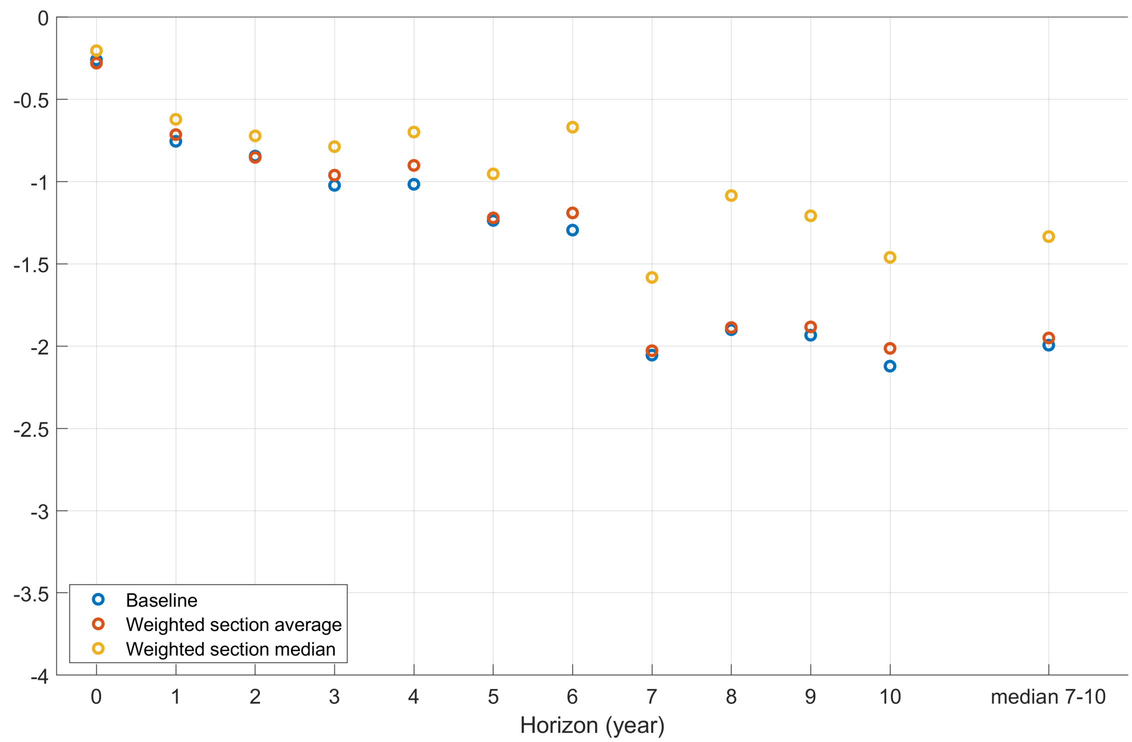
TABLE A3: HS Sections

Code	Name
7	PLASTICS AND ARTICLES THEREOF; RUBBER AND ARTICLES THEREOF
8	RAW HIDES AND SKINS, LEATHER, FURSKINS AND ARTICLES THEREOF;
	SADDLERY AND HARNESS; TRAVEL GOODS
9	WOOD AND ARTICLES OF WOOD; WOOD CHARCOAL;
	CORK AND ARTICLES OF CORK; MANUFACTURES OF STRAW,
	OF ESPARTO OR OF OTHER PLAITING MATERIALS;
	BASKETWARE AND WICKERWORK
10	PULP OF WOOD OR OF OTHER FIBROUS CELLULOSIC MATERIAL;
	RECOVERED (WASTE AND SCRAP) PAPER OR PAPERBOARD;
	PAPER AND PAPERBOARD AND ARTICLES THEREOF
11	TEXTILES AND TEXTILE ARTICLES
13	ARTICLES OF STONE, PLASTER, CEMENT, ASBESTOS, MICA OR SIMILAR MATERIALS
15	BASE METALS AND ARTICLES OF BASE METAL
	CERAMIC PRODUCTS; GLASS AND GLASSWARE
16	MACHINERY AND MECHANICAL APPLIANCES;
	ELECTRICAL EQUIPMENT; PARTS THEREOF; SOUND RECORDERS AND REPRODUCERS,
	TELEVISION IMAGE AND SOUND RECORDERS AND
	REPRODUCERS, AND PARTS AND ACCESSORIES OF SUCH ARTICLES
	ARTIFICIAL FLOWERS; ARTICLES OF HUMAN HAIR
18	OPTICAL, PHOTOGRAPHIC, CINEMATOGRAPHIC, MEASURING,
	CHECKING, PRECISION, MEDICAL OR SURGICAL INSTRUMENTS AND APPARATUS;
	CLOCKS AND WATCHES; MUSICAL INSTRUMENTS; PARTS AND ACCESSORIES THEREOF
20	MISCELLANEOUS MANUFACTURED ARTICLES
	Aggregated
1	LIVE ANIMALS; ANIMAL PRODUCTS
2	VEGETABLE PRODUCTS
3	ANIMAL OR VEGETABLE FATS AND OILS AND THEIR CLEAVAGE PRODUCTS
	HANDBAGS AND SIMILAR CONTAINERS; ARTICLES OF ANIMAL GUT (OTHER THAN SILK-WORM GUT)
4	PREPARED EDIBLE FATS;ANIMAL OR VEGETABLE WAXES
	PREPARED FOODSTUFFS;
	BEVERAGES, SPIRITS AND VINEGAR; TOBACCO AND MANUFACTURED TOBACCO SUBSTITUTES
5	MINERAL PRODUCTS
6	PRODUCTS OF THE CHEMICAL OR ALLIED INDUSTRIES
12	FOOTWEAR, HEADGEAR, UMBRELLAS, SUN UMBRELLAS,
	WALKING-STICKS, SEAT-STICKS, WHIPS, RIDING-CROPS AND PARTS THEREOF;
	PREPARED FEATHERS AND ARTICLES MADE THEREWITH;
14	NATURAL OR CULTURED PEARLS, PRECIOUS OR SEMI-PRECIOUS
	STONES, PRECIOUS METALS, METALS CLAD WITH PRECIOUS METAL
	AND ARTICLES THEREOF; IMITATION JEWELLERY; COIN
17	VEHICLES, AIRCRAFT, VESSELS AND ASSOCIATED TRANSPORT EQUIPMENT
19	ARMS AND AMMUNITION; PARTS AND ACCESSORIES THEREOF
21	WORKS OF ART, COLLECTORS' PIECES AND ANTIQUES

Notes: This table describes the 21 internationally compatible HS "Sections", which are groupings of HS product codes. We also list the 9 HS Sections that we aggregate in the main text into a Section 'aggregate', as there is insufficient variation in tariffs in these sections to estimate the elasticity. Figures 3 reports the elasticity estimates by section, and Figure B1 reports trade-weighted means and medians of section-specific elasticities.

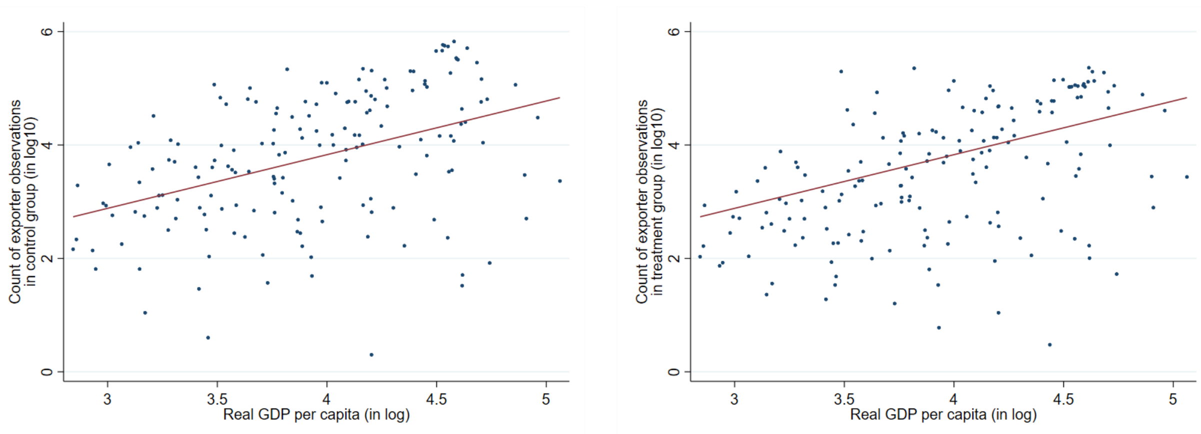
Appendix B Robustness

FIGURE B1: Trade elasticities: Full Sample Pooled vs. Trade-Weighted Sectoral Averages



Notes: The blue circles reproduce the baseline elasticity point estimates depicted in Figure 2. The red circles display world trade-weighted means of the HS section-specific elasticities reported in Figure 3. The yellow circles display world trade-weighted medians of the HS section-specific elasticities reported in Figure 3. Weighting uses the 2006 shares of world trade, and excludes the estimates of the combined HS aggregate section as described in the text.

FIGURE B2: Country Variation

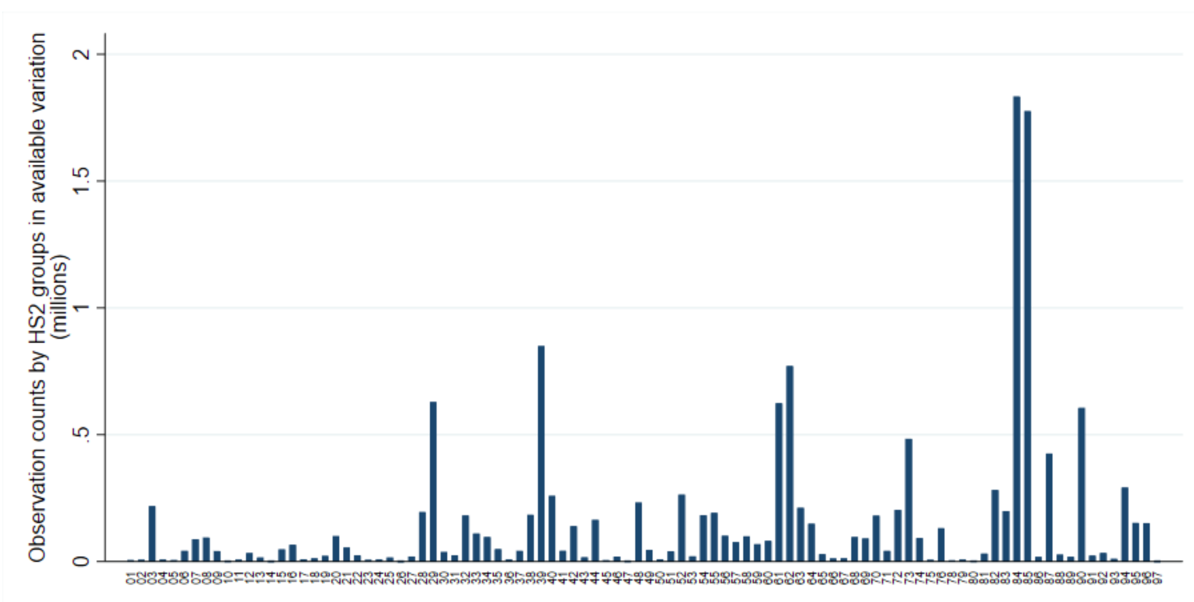


Control

Treatment

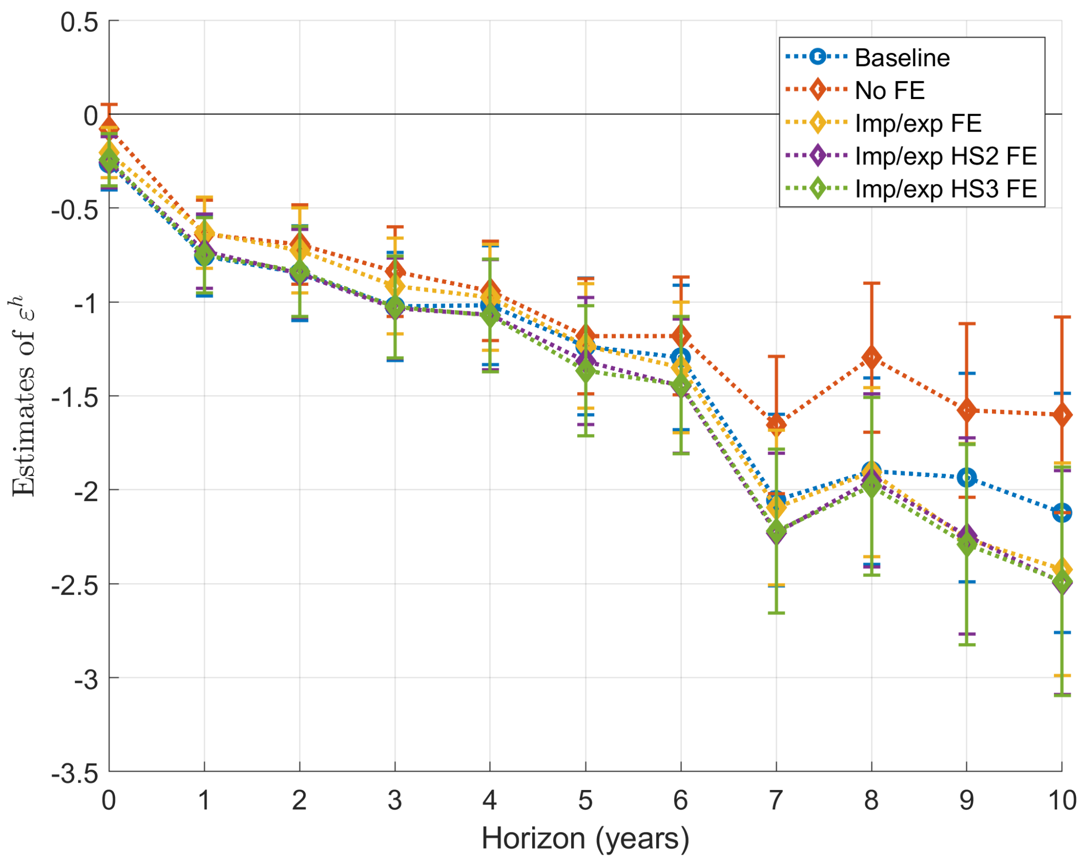
Notes: This figure plots the (log) counts a country appears in the control group (left panel) and in the treatment group (right panel) against log real PPP-adjusted per capita income from the Penn World Tables, after taking out the variation absorbed by the fixed effects and imposing the sample restrictions. The line depicts the OLS fit.

FIGURE B3: Product Variation



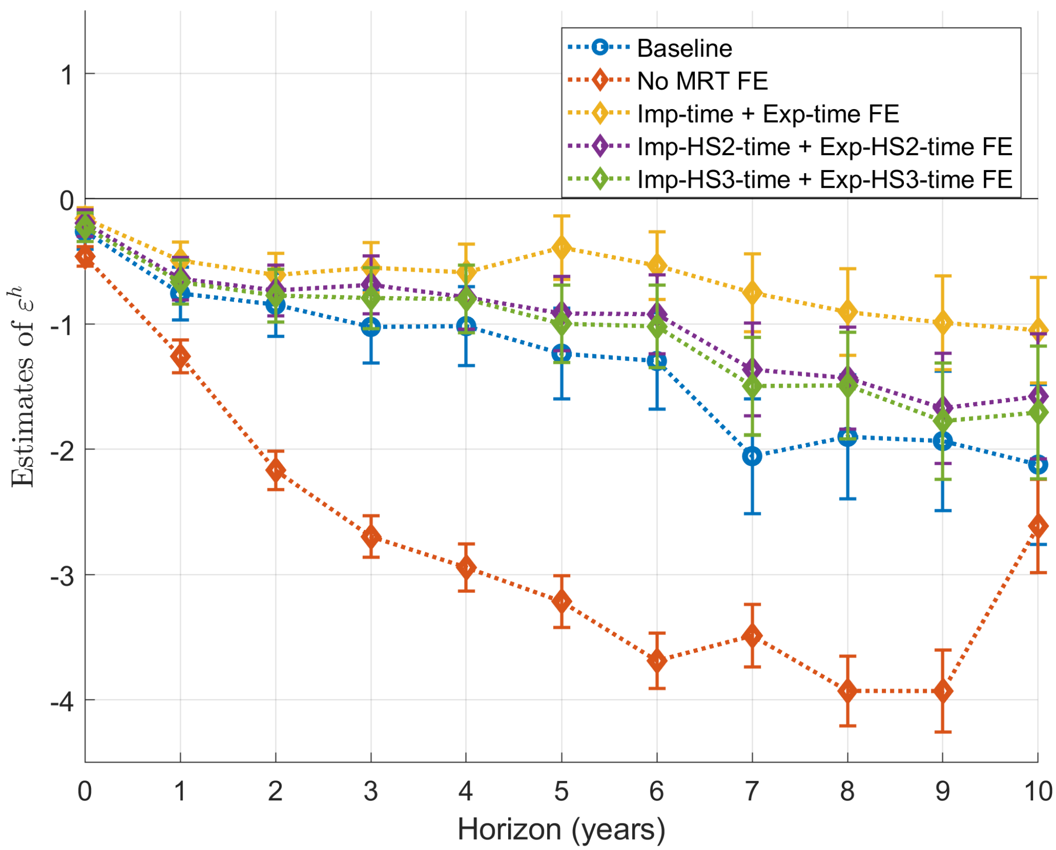
Notes: This figure plots the frequency of observations belonging to each HS-2 category, after taking out the variation absorbed by the fixed effects and imposing the sample restrictions.

Figure B4: Robustness: The Role of Bilateral Fixed Effects



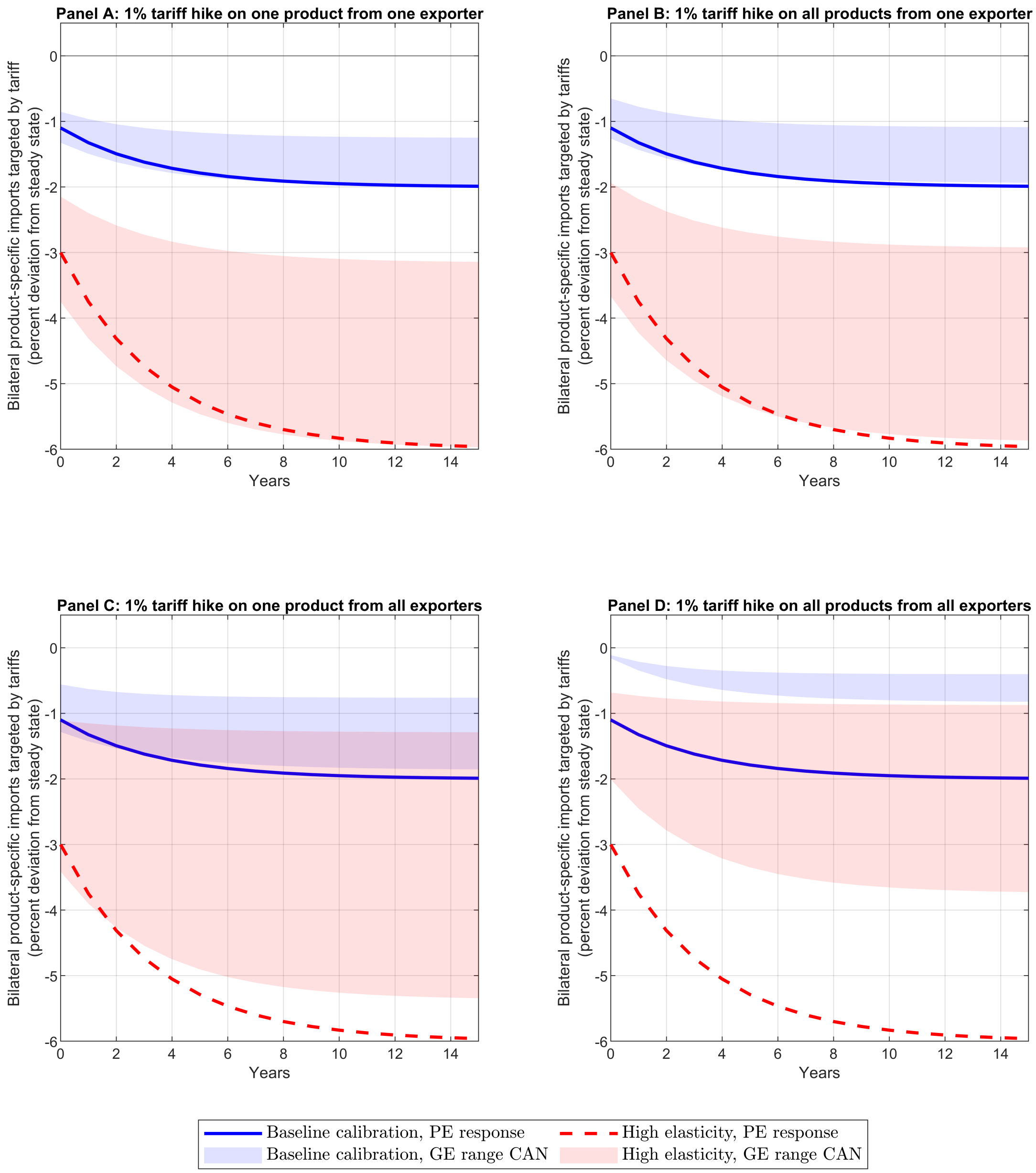
Notes: This figure displays estimates of the trade elasticity based on specification (4), with the baseline instrument (5), and including one lag of the changes in tariffs and trade as pre-trend controls. All specifications include exporter-HS4-year and importer-HS4-year fixed effects. The bilateral fixed effects are either importer-exporter-HS4 (the baseline), importer-exporter-HS3, importer-exporter-HS2, importer-exporter, or no bilateral fixed effects. The bars display 95% confidence intervals. Standard errors are clustered at the bilateral country-pair-product level.

Figure B5: Robustness: The Role of Multilateral Resistance Terms



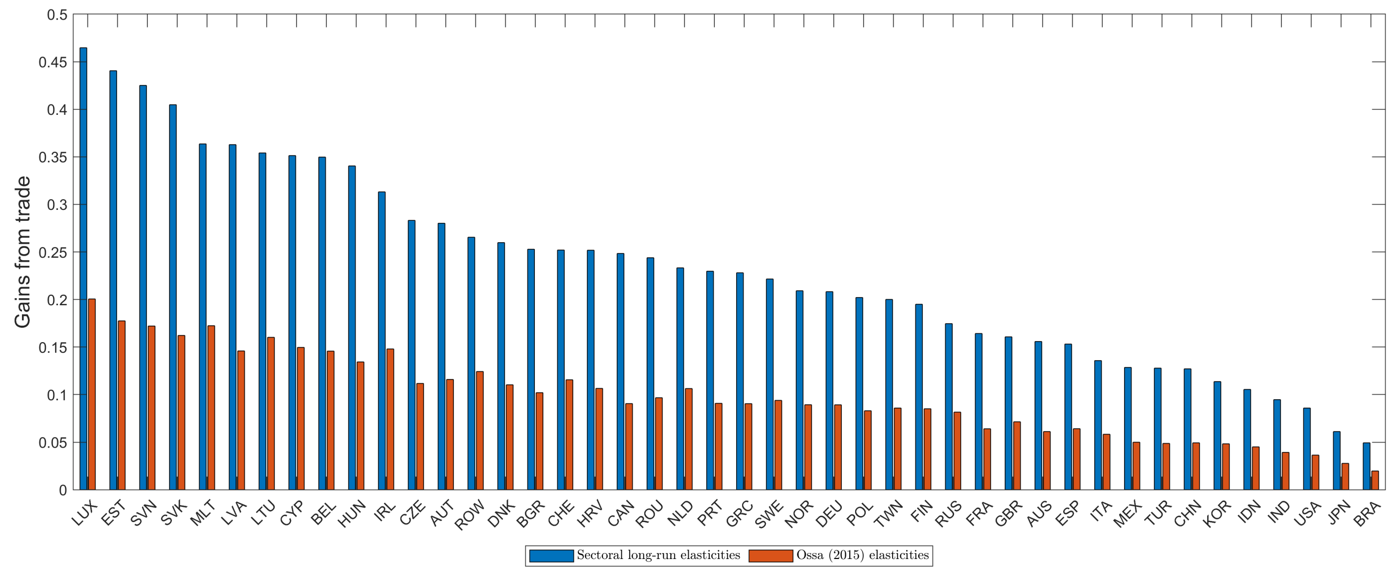
Notes: This figure displays estimates of the trade elasticity based on specification (4), with the baseline instrument (5) and including one lag of the changes in tariffs and trade as pre-trend controls. All specifications include importer-exporter-HS4 fixed effects. The multilateral resistance term (MRT) fixed effects are either importer- and exporter-year-HS4 (the baseline); importer- and exporter-year-HS3; importer- and exporter-HS2; importer- and exporter-year; or no multilateral fixed effects. The bars display 95% confidence intervals. Standard errors are clustered at the bilateral country-pair-product level.

Figure B6: General Equilibrium Trade Responses: Canadian Imports



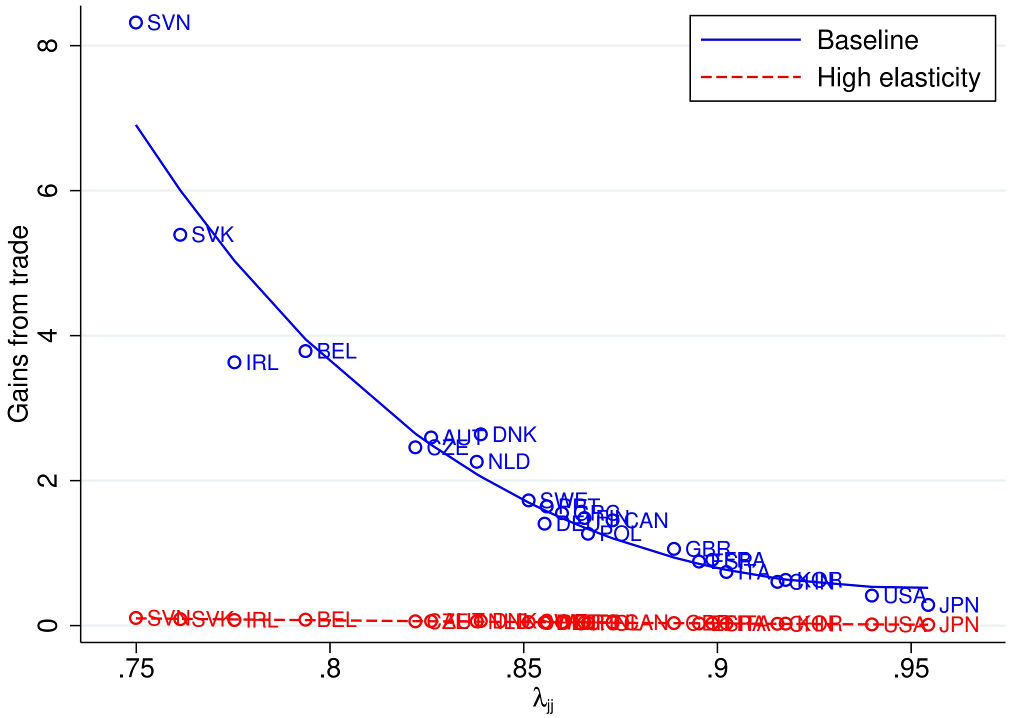
Notes: This table reports the impulse responses of Canadian imports to unexpected and permanent 1% tariff hikes in partial equilibrium (solid blue lines and dashed red lines) and in general equilibrium (shaded areas). The shaded areas represent the ranges of impulse response functions in GE taken over exporters and sectors. In the baseline calibration $\sigma = 1.1$ and $\chi = 0.82$, so that the long-run elasticity $\varepsilon = 2$. In the high elasticity calibration, $\sigma = 3$ and $\chi = 1$, so that $\varepsilon = 6$. See Appendix Table D1 for details on the calibration.

Figure B7: Gains From Trade: Multiple Sectors



Notes: Gains from trade relative to autarky are computed using the formula $1 - \sum_s \lambda_{jj,s}^{-\beta_{j,s}/\theta_s}$, where $\beta_{j,s}$ is the share of sector s in country j's total absorption and $\lambda_{jj,s}$ is 1 minus the import share in sector s. "Sectoral long-run elasticities" refer to the HS-section level elasticities estimated in Section III.A. We use the median estimate between years 7-10 for each section as the long-run value. For a comparison, the red bars use elasticities obtained from Ossa (2015). Data come from the 2006 World Input-Output Database (WIOD). The input-output table is converted to HS classification using an OECD concordance between ISIC and HS. The GTAP sector estimates from Ossa (2015) are converted to the HS classification using GTAP's concordance table between GTAP sectors and HS classifications. The number of HS-6 categories in each GTAP-HS section pair is used as a weight.

Figure B8: Gains From Trade: Dynamic Krugman Model



Notes: This figure reports the gains from trade relative to autarky in the dynamic Krugman model as described in Appendix D. λ_{jj} denotes the domestic absorption share.

Table B1: Local Projections of Tariffs and Trade: Coefficients for Every Horizon

	Panel A: Tariffs			Panel B: Trade		
	Baseline	Zero Lag	Five Lags	Baseline	Zero Lag	Five Lags
	(1)	(2)	(3)	(4)	(5)	(6)
$t-6$	-0.10***	-0.09***	-0.10***	0.10	0.03	0.31*
	(0.01)	(0.00)	(0.01)	(0.13)	(0.11)	(0.16)
$t-5$	-0.02***	-0.03***	.	0.22*	0.27***	.
	(0.00)	(0.00)	.	(0.12)	(0.11)	.
$t-4$	-0.04***	-0.02***	.	0.00	-0.06	.
	(0.00)	(0.00)	.	(0.11)	(0.09)	.
$t-3$	-0.05***	-0.09***	.	0.07	-0.02	.
	(0.00)	(0.00)	.	(0.10)	(0.09)	.
$t-2$	-0.13***	-0.03***	.	0.24***	0.13	.
	(0.00)	(0.00)	.	(0.09)	(0.09)	.
$t-1$	.	-0.31***	.	.	0.15**	.
	.	(0.00)	.	.	(0.07)	.
t	.	.	.	-0.26***	-0.15***	0.17
	.	.	.	(0.07)	(0.05)	(0.14)
$t+1$	0.89***	0.85***	0.84***	-0.67***	-0.53***	-0.11
	(0.00)	(0.00)	(0.01)	(0.10)	(0.07)	(0.18)
$t+2$	0.85***	0.83***	0.79***	-0.72***	-0.59***	-0.13
	(0.00)	(0.00)	(0.01)	(0.11)	(0.08)	(0.21)
$t+3$	0.83***	0.82***	0.77***	-0.85***	-0.76***	-0.48**
	(0.01)	(0.00)	(0.01)	(0.12)	(0.09)	(0.24)
$t+4$	0.82***	0.81***	0.75***	-0.83***	-0.75***	-0.21
	(0.01)	(0.00)	(0.01)	(0.13)	(0.09)	(0.27)
$t+5$	0.81***	0.82***	0.72***	-1.00***	-0.92***	-0.82***
	(0.01)	(0.00)	(0.01)	(0.15)	(0.10)	(0.31)
$t+6$	0.78***	0.79***	0.66***	-1.01***	-0.88***	-0.50
	(0.01)	(0.00)	(0.01)	(0.15)	(0.10)	(0.32)
$t+7$	0.69***	0.75***	0.59***	-1.43***	-1.15***	-1.38***
	(0.01)	(0.00)	(0.01)	(0.16)	(0.11)	(0.35)
$t+8$	0.67***	0.72***	0.55***	-1.27***	-1.15***	-0.93**
	(0.01)	(0.00)	(0.01)	(0.17)	(0.12)	(0.39)
$t+9$	0.70***	0.73***	0.63***	-1.35***	-0.99***	-1.37***
	(0.01)	(0.00)	(0.02)	(0.20)	(0.12)	(0.51)
$t+10$	0.71***	0.72***	0.64***	-1.52***	-1.05***	-1.64**
	(0.01)	(0.01)	(0.02)	(0.23)	(0.14)	(0.65)

Notes: This table presents the results from estimating the local projections equations (3) (Panel A) and (2) (Panel B). The dependent variable for negative time horizons is the one-period change in the variable of interest. For instance, the dependent variable in column (2) for horizon $t-1$ is $\ln \tau_{i,j,p,t-1} - \ln \tau_{i,j,p,t-2}$. The first column in each panel presents the baseline local projects results, while the second and third columns in each panel present results with 2 and 5 lags of tariffs and trade as pre-trend controls respectively. Standard errors clustered by country-pair-product are in parentheses. ***, ** and * denote significance at the 99, 95 and 90% levels.

Table B2: Trade Elasticity: Estimates and First Stage F-Statistics

	Baseline IV	F-stat	Distributed Lag	SW F-stat
t	-0.26***	91422	-0.41	20536
	(0.07)		(0.34)	
$t+1$	-0.76***	42231	-0.52	18831
	(0.11)		(0.47)	
$t+2$	-0.85***	36469	-0.92	22499
	(0.13)		(0.59)	
$t+3$	-1.02***	28537	-1.58**	22570
	(0.15)		(0.68)	
$t+4$	-1.02***	23771	-1.60**	16227
	(0.16)		(0.77)	
$t+5$	-1.24***	22697	-2.10**	12463
	(0.19)		(0.86)	
$t+6$	-1.30***	19439	-2.18**	14722
	(0.20)		(0.93)	
$t+7$	-2.06***	15481	-2.71***	13473
	(0.23)		(1.02)	
$t+8$	-1.90***	13933	-2.80**	13475
	(0.25)		(1.11)	
$t+9$	-1.93***	10201	-3.08***	14278
	(0.28)		(1.18)	
$t+10$	-2.12***	8252	-3.17**	10962
	(0.32)		(1.25)	

Notes: This table presents the first-stage F-statistics for the main estimates. For the Distributed Lag model we report the Sanderson-Windmeijer F-statistic to test for weak instruments as we have 11 instruments and 11 endogenous variables.

Table B3: Trade Elasticity: Comparison to Existing Estimates of Responses to Tariffs

Papers	Method	Estimate(s)	Time Period	Country Sample
Country-Level				
Baier and Bergstrand (2001)	Single long difference, no MRT FEs	-4.49	1958-60 to 1986-1988	16 OECD countries
Anderson and Marcouiller (2002)	Ratios, US Base country	-4.8	1996	58 countries
Estevadeordal, Frantz, and Taylor (2003)	Log-levels panel, gravity controls	-0.8 to -1.6	1913, 1928, 1938	28 countries
2-digit sectors				
Nahuis (2004)	Log-levels cross section, gravity controls	-38 to $+46.5$	1998	27 countries
Tharakan, Beveren, and Ourti (2005)	Log-levels panel	insignificant	-	India
Fink, Mattoo, and Neagu Constantinescu (2005)	Log-levels cross-section, MRT, gravity controls	-0.5 to -3.5	1999	
Francois and Woerz (2009)	Log-levels panel, gravity controls	-2 to -5.5	1996-2005	EU, US, 20-46 partners
Dutt and Traca (2010)	Panel, gravity variables, Country FE + Country-level controls	-2.1 to -2.6	1980-2004	28 sectors
Caliendo and Parro (2015)	Cross-sectional double differencing	-0.37 to -51.08	1993	27 countries
3-digit sectors				
Head and Ries (2001)	Log-levels Panel	-7.9 to -11.4	1990-1995	US, Canada
5 digit SITC/HS6				
Hummels (2001)	Log-levels cross-section, MRT + gravity variables	-3 to -8	1992	6 FTAA countries + New Zealand
Hertel et al. (2007)	Log-levels cross-section, MRT, gravity variables	-1.8 to -34.4	1992	6 FTAA countries + New Zealand
Romalis (2007)	Log-levels diff-in-diff	-0.56 to -10.9	1990-1999	US, Mexico, Canada, EU and Rest-of-World
Fontagné, Guimbard, and Orefice (2022)	Log-levels panel MRT + gravity controls	-0.38 to -122.97	2001,'04,'07, '10,'13,'16	150+ importers
Our paper	Local Projections IV diff-in-diff	-0.75 to -2.25	1995-2018	180+ countries
HS8-HS10 (Firm-level)				
Bas, Mayer, and Thoenig (2017)	Log-levels cross-section with FEs, tetrads, Tobit	-2.5 to -5.5	2000	China, France and all export destinations
Fitzgerald and Haller (2018)	Firm-product-destination panel	-1.6 to -3.55		Ireland and top import destinations

Notes: This table summarizes the elasticity estimates of the papers closest to ours in methodology. MRT abbreviates multilateral resistance terms fixed effects.

Table B4: Elasticity Estimates: Alternative Approaches – Constant Sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Log Levels			5-year Log Differences					10-year
	No FE	Multilateral FE	Multilateral + Bilateral FE	OLS	2SLS	Baseline IV			
$\ln \tau_{i,j,p,t}$	-8.01***	-10.95***	-0.75***	-1.15***	-0.87***	-1.34***	-1.14***	-1.61***	-1.93***
	(0.07)	(0.15)	(0.09)	(0.07)	(0.08)	(0.22)	(0.26)	(0.30)	(0.36)
R^2	0.02	0.44	0.62	0.22					
Obs	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
First stage F					71700	11505	9331	4801	4171
Fixed effects									
Imp×HS4×year, Exp×HS4×year		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Imp×Exp×HS4			Yes				Yes	Yes	Yes
pre-trend controls								Yes	Yes

Notes: This table compares alternative approaches of estimating trade elasticities on a constant sample. The dependent variables are log levels of trade values (columns 1-3) and log-differences of trade flows (columns 4-9), and the independent variable of interest is the log of tariffs (columns 1-3), 5-year log-differences of tariffs (columns 4-8), and the 10-year log-difference of tariffs (column 9). Column 1 reports the results with no fixed effects. Column 2 adds importer-HS4-year and exporter-HS4-year fixed effects. Column 3 further adds importer-exporter-HS4 fixed effects. Column 4 estimates the coefficient by OLS. Column 5 reports the all data/all tariffs 2SLS as explained in the text. Columns 6-9 present the results using our baseline IV. The specifications with pre-trend controls additionally include log-changes in tariffs from $t-2$ to $t-1$, instrumented with our lagged baseline instrument, and log-changes in trade from $t-2$ to $t-1$. The reported R^2s include the explanatory power of the fixed effects. Standard errors clustered by country-pair-product are in parentheses. *** denotes significance at the 99% level. Numbers of observations are reported in millions.

TABLE B5: "Traditional Gravity" Elasticity Estimates in Log-Levels, HS6 Multilateral Resistance Terms

	No Bilateral (1)	Country-pair (2)	Country-pair×HS2 (3)	Country-pair×HS3 (4)	Country-pair×HS4 (5)
$\ln \tau_{i,j,p,t}$	-12.62***	-1.70***	-1.36***	-1.28***	-1.04***
	(0.08)	(0.03)	(0.02)	(0.02)	(0.02)
R^2	0.55	0.67	0.70	0.71	0.76
Obs	103.1	103.1	102.9	102.7	101.7
Bilateral Fixed Effects					
	None	Imp×Exp	Imp×Exp×HS2	Imp×Exp×HS3	Imp×Exp×HS4

Notes: This table presents the results from estimating the trade elasticity in log-levels where the multilateral resistance terms are at the HS6 level. The dependent variable is the log of trade value. All specifications include importer-HS6-year and exporter-HS6-year fixed effects. Column 1 reports the results with no bilateral fixed effects. Column 2 adds country-pair fixed effects, Column 3 includes country-pair-HS2 fixed effects, column 4 includes country-pair-HS3 fixed effects, and Column 4 uses country-pair-HS4 fixed effects. The reported R^2s include the explanatory power of the fixed effects. Standard errors, clustered at the importer-exporter-HS4 level, are in parentheses. ***, ** and * denote significance at the 99, 95, and 90% levels. Number of observations are reported in millions.

Table B6: Trade Elasticity, Every Horizon, Robustness: Pre-Trends, Alternative Clustering, Alternative Samples

	Baseline	No Lags	Five Lags	FE50	Two-way Clustering	Constant Sample	Alternative Control Group	Extensive Case 1	Extensive Case 2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
t	-0.26***	-0.15***	0.17	-0.23**	-0.26***	-0.59**	-0.19**	0.02	-0.08
	(0.07)	(0.05)	(0.14)	(0.09)	(0.10)	(0.29)	(0.08)	(0.04)	(0.06)
Obs	31.7	41.5	14.6	17.6	31.7	5.0	27.3	131.0	56.4
$t+1$	-0.76***	-0.63***	-0.13	-0.60***	-0.76***	-0.10	-0.49***	-0.48***	-0.81***
	(0.11)	(0.08)	(0.21)	(0.13)	(0.14)	(0.38)	(0.12)	(0.06)	(0.09)
Obs	26.2	32.8	12.5	15.2	26.2	5.0	22.6	108.1	49.1
$t+2$	-0.85***	-0.71***	-0.16	-0.72***	-0.85***	-0.76*	-0.45***	-0.43***	-0.73***
	(0.13)	(0.09)	(0.26)	(0.16)	(0.19)	(0.44)	(0.14)	(0.07)	(0.10)
Obs	23.3	29.2	11.1	13.8	23.3	5.0	20.1	97.0	45.2
$t+3$	-1.02***	-0.93***	-0.63**	-0.86***	-1.02***	-0.89*	-0.74***	-0.59***	-0.95***
	(0.15)	(0.10)	(0.31)	(0.17)	(0.20)	(0.47)	(0.16)	(0.08)	(0.11)
Obs	20.8	26.2	9.8	12.5	20.8	5.0	17.9	87.2	41.5
$t+4$	-1.02***	-0.92***	-0.29	-0.78***	-1.02***	-0.77	-0.61***	-0.45***	-0.85***
	(0.16)	(0.12)	(0.36)	(0.19)	(0.23)	(0.48)	(0.17)	(0.10)	(0.12)
Obs	18.7	23.5	8.5	11.3	18.7	5.0	16.0	77.8	37.9
$t+5$	-1.24***	-1.11***	-1.15***	-1.01***	-1.24***	-0.92**	-0.79***	-0.73***	-1.18***
	(0.19)	(0.12)	(0.43)	(0.22)	(0.25)	(0.44)	(0.20)	(0.10)	(0.12)
Obs	16.7	21.1	7.3	10.2	16.7	5.0	14.3	69.7	34.6
$t+6$	-1.30***	-1.11***	-0.75	-1.05***	-1.30***	-0.53	-0.57***	-0.86***	-1.21***
	(0.20)	(0.13)	(0.48)	(0.23)	(0.27)	(0.46)	(0.22)	(0.10)	(0.12)
Obs	14.9	18.9	6.2	9.2	14.9	5.0	12.6	62.1	31.3
$t+7$	-2.06***	-1.52***	-2.33***	-1.85***	-2.06***	-0.99**	-1.38***	-0.90***	-1.50***
	(0.23)	(0.15)	(0.59)	(0.27)	(0.36)	(0.49)	(0.25)	(0.11)	(0.14)
Obs	13.2	17.0	5.2	8.2	13.2	5.0	11.1	55.2	28.4
$t+8$	-1.90***	-1.60***	-1.69**	-1.89***	-1.90***	-1.09**	-1.08***	-0.69***	-1.43***
	(0.25)	(0.16)	(0.71)	(0.29)	(0.46)	(0.51)	(0.27)	(0.13)	(0.16)
Obs	11.5	15.0	4.4	7.2	11.5	5.0	9.6	48.5	25.4
$t+9$	-1.93***	-1.35***	-2.15***	-1.78***	-1.93***	-1.60***	-1.09***	-1.00***	-1.65***
	(0.28)	(0.16)	(0.81)	(0.32)	(0.50)	(0.55)	(0.31)	(0.14)	(0.16)
Obs	9.9	13.1	3.8	6.2	9.9	5.0	8.2	41.8	22.4
$t+10$	-2.12***	-1.46***	-2.55**	-1.76***	-2.12***	-1.82***	-1.60***	-0.94***	-1.64***
	(0.32)	(0.19)	(1.02)	(0.37)	(0.33)	(0.54)	(0.38)	(0.15)	(0.18)
Obs	8.3	11.3	3.2	5.2	8.3	5.0	6.8	35.1	19.2

Notes: This table presents robustness exercises for the results from estimating equation (4). All specifications include importer-HS4-year, exporter-HS4-year, and importer-exporter-HS4 fixed effects, and the baseline pre-trend controls (one lag of each the log change in tariffs and trade) unless otherwise specified. Columns 2 and 3 vary the pre-trend controls (including alternatively zero lags or five lags of import growth and tariff changes). Column 4 reports the results when the sample is restricted to fixed-effects clusters with a minimum of 50 observations per cluster. Column 6 restricts the sample to a constant sample across horizons. Column 7 reports results where the control group only contains observations with zero tariff changes. Column 8 presents results including the extensive margin using the inverse hyperbolic sine transformation for trade flows, and all zero trade observations for importer-exporter-section pair with ever positive trade. Column 9 presents results including the extensive margin using the inverse hyperbolic sine transformation for trade flows, and only zero trade observations when trade switches from zero to positive, or vice versa. Standard errors are clustered at the importer-exporter-HS4 level, except in Column 5 where they are additionally clustered by year. ***, **, and * indicate significance at the 99, 95, and 90 percent level respectively. Observations are reported in millions.

Table B7: Trade Elasticity, Every Horizon, Robustness: Alternative Instruments, Outcomes, and Samples

	Baseline	All data/ MFN Tariffs	Top 5 Maj. Partners	Quantities	Unit Values	Weighted	SD1	PTA	TTB
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
t	-0.26***	-0.28***	-0.24***	-0.18*	-0.05	-0.24***	-0.31***	-0.24***	-0.26***
	(0.07)	(0.03)	(0.05)	(0.09)	(0.06)	(0.08)	(0.10)	(0.07)	(0.07)
Obs	31.7	57.1	39.0	31.7	31.7	31.6	28.7	31.8	31.7
$t+1$	-0.76***	-0.62***	-0.67***	-0.66***	-0.03	-0.82***	-0.89***	-0.73***	-0.76***
	(0.11)	(0.05)	(0.08)	(0.14)	(0.08)	(0.12)	(0.14)	(0.11)	(0.11)
Obs	26.2	47.2	32.1	26.2	26.2	26.2	23.8	26.3	26.2
$t+2$	-0.85***	-0.65***	-0.72***	-0.66***	-0.14	-0.94***	-0.86***	-0.83***	-0.84***
	(0.13)	(0.05)	(0.09)	(0.16)	(0.09)	(0.14)	(0.17)	(0.13)	(0.13)
Obs	23.3	42.3	28.6	23.3	23.3	23.3	21.1	23.4	23.3
$t+3$	-1.02***	-0.65***	-0.86***	-0.81***	-0.13	-1.05***	-1.23***	-0.97***	-1.02***
	(0.15)	(0.06)	(0.10)	(0.18)	(0.10)	(0.16)	(0.20)	(0.15)	(0.15)
Obs	20.8	38.2	25.6	20.8	20.8	20.8	18.9	20.9	20.8
$t+4$	-1.02***	-0.66***	-0.87***	-0.80***	-0.09	-1.08***	-1.17***	-0.98***	-1.02***
	(0.16)	(0.07)	(0.11)	(0.20)	(0.11)	(0.18)	(0.22)	(0.16)	(0.16)
Obs	18.7	34.4	23.0	18.7	18.7	18.7	16.9	18.8	18.7
$t+5$	-1.24***	-0.72***	-1.08***	-1.42***	0.29**	-1.21***	-1.18***	-1.12***	-1.24***
	(0.19)	(0.07)	(0.12)	(0.23)	(0.13)	(0.21)	(0.25)	(0.19)	(0.19)
Obs	16.7	30.9	20.6	16.7	16.7	16.7	15.1	16.8	16.7
$t+6$	-1.30***	-0.78***	-1.08***	-1.37***	0.13	-1.45***	-1.27***	-1.21***	-1.30***
	(0.20)	(0.08)	(0.13)	(0.24)	(0.13)	(0.22)	(0.26)	(0.20)	(0.20)
Obs	14.9	27.7	18.4	14.9	14.9	14.9	13.5	15.0	14.9
$t+7$	-2.06***	-0.94***	-1.53***	-2.17***	0.16	-2.14***	-1.99***	-1.97***	-2.06***
	(0.23)	(0.09)	(0.16)	(0.29)	(0.16)	(0.26)	(0.32)	(0.23)	(0.23)
Obs	13.2	24.6	16.3	13.2	13.2	13.2	12.0	13.3	13.2
$t+8$	-1.90***	-1.00***	-1.51***	-2.08***	0.20	-1.97***	-1.95***	-1.85***	-1.90***
	(0.25)	(0.10)	(0.17)	(0.32)	(0.17)	(0.28)	(0.35)	(0.25)	(0.25)
Obs	11.5	21.7	14.2	11.5	11.5	11.5	10.4	11.6	11.5
$t+9$	-1.93***	-0.97***	-1.58***	-1.66***	-0.18	-2.06***	-2.19***	-1.91***	-1.93***
	(0.28)	(0.11)	(0.19)	(0.35)	(0.19)	(0.32)	(0.39)	(0.29)	(0.28)
Obs	9.9	18.7	12.2	9.9	9.9	9.8	8.9	9.9	9.9
$t+10$	-2.12***	-0.87***	-1.48***	-1.76***	-0.08	-2.37***	-2.36***	-2.08***	-2.12***
	(0.32)	(0.12)	(0.22)	(0.41)	(0.22)	(0.37)	(0.44)	(0.33)	(0.32)
Obs	8.3	15.9	10.3	8.3	8.3	8.3	7.5	8.4	8.3

Notes: This table presents alternative estimates for the results from estimating equation (4), varying the instrument, outcome variable, or sample. All specifications include importer-HS4-year, exporter-HS4-year, and importer-exporter-HS4 fixed effects, and the baseline pre-trend controls (one lag of each the log change in tariffs and trade). Column 2 uses an alternative sample where all trade partners subject to the MFN regime are included. Column 3 presents results where the sample excludes only the top-5 major MFN trade partners. Column 4 reports results for quantities, and column 5 the results for unit values. Column 6 presents results for a weighted specification where $t-1$ log trade values are used as weights. Column 7 reports the results based on a sample where tariffs do not vary within an importer-exporter-HS6-year observation. Column 8 presents results where we assign observations covered by a PTA listed in the WTO PTA Database to the control group. Column 9 reports the results after dropping country-pair-product-year observations where imports were subject to temporary trade barriers. Standard errors are clustered at the importer-exporter-HS4 level. ***, **, and * indicate significance at the 99, 95, and 90 percent level respectively. Observations are reported in millions.

Table B8: Trade Elasticity: Further Robustness

	Uruguay Round		HS6 Multilateral Effects		Distributed Lag
	All data/all tariffs 2SLS	Baseline IV	All data/all tariffs 2SLS	Baseline IV	Baseline IV
	(1)	(2)	(3)	(4)	(5)
t	-0.28	-0.18	-0.19***	0.08	-0.41
	(0.18)	(0.85)	(0.02)	(0.11)	(0.34)
Obs	0.9	0.6	54.3	30.2	6.1
$t+1$	-1.02*	-2.01	-0.26***	-0.68***	-0.52
	(0.61)	(2.39)	(0.02)	(0.13)	(0.47)
Obs	0.8	0.5	54.3	24.9	6.1
$t+2$	-0.63	-1.49	-0.28***	-0.60***	-0.92
	(0.71)	(2.66)	(0.03)	(0.16)	(0.59)
Obs	0.8	0.5	48.5	22.2	6.1
$t+3$	-1.42**	-5.09**	-0.29***	-0.59***	-1.58**
	(0.59)	(2.47)	(0.03)	(0.17)	(0.68)
Obs	0.8	0.5	43.7	19.8	6.1
$t+4$	-1.50**	-1.43	-0.37***	-0.77***	-1.60**
	(0.62)	(1.96)	(0.04)	(0.19)	(0.77)
Obs	0.8	0.5	39.5	17.8	6.1
$t+5$	-1.23*	-2.08	-0.41***	-1.04***	-2.10**
	(0.72)	(2.46)	(0.04)	(0.22)	(0.86)
Obs	0.7	0.4	35.6	15.9	6.1
$t+6$	-1.36**	-1.15	-0.45***	-1.09***	-2.18**
	(0.68)	(2.31)	(0.04)	(0.22)	(0.93)
Obs	0.7	0.4	31.9	14.2	6.1
$t+7$	-1.62*	0.26	-0.43***	-1.37***	-2.71***
	(0.88)	(2.90)	(0.05)	(0.27)	(1.02)
Obs	0.7	0.4	28.6	12.6	6.1
$t+8$	-1.90**	-4.74	-0.35***	-0.99***	-2.80**
	(0.86)	(2.93)	(0.05)	(0.29)	(1.11)
Obs	0.7	0.5	25.4	11.0	6.1
$t+9$	-1.07	-3.61	-0.41***	-0.98***	-3.08***
	(0.84)	(2.52)	(0.05)	(0.33)	(1.18)
Obs	0.7	0.5	22.2	9.4	6.1
$t+10$	-0.42	-2.97	-0.50***	-0.47	-3.17**
	(1.05)	(3.28)	(0.05)	(0.36)	(1.25)
Obs	0.6	0.4	19.0	8.0	6.1

Notes: This table presents the results from estimating the trade elasticity using both all data/all tariffs 2SLS (column 1) and the baseline instrument (column 2) for tariff changes only in years 1995-1997 ("Uruguay round"). These specifications include importer-HS4-year, exporter-HS4-year, and importer-exporter-HS4 fixed effects. Columns (3) and (4) present the all data/all tariffs 2SLS and baseline IV specifications when the multilateral resistance terms are country-HS6-year level. In these columns we drop the bilateral fixed effect. Columns (1) to (4) also include the baseline pre-trend controls (one lag). Column 5 presents results from a distributed lag model. This specification includes importer-HS4-year, exporter-HS4-year, and importer-exporter-HS4 fixed effects. Standard errors are clustered at the importer-exporter-HS4 level. ***, **, and * indicate significance at the 99, 95, and 90 percent level respectively. Observations are reported in millions.

Table B9: Gains from Trade

Country	$\theta = -1$	$\theta = -5$	$\theta = -10$
G7			
Canada	14.56%	2.76%	1.37%
France	11.28%	2.16%	1.07%
Germany	16.91%	3.17%	1.57%
Italy	10.83%	2.08%	1.03%
Japan	4.78%	0.94%	0.47%
UK	12.51%	2.39%	1.19%
US	6.40%	1.25%	0.62%
Major Emerging Markets			
Brazil	3.58%	0.71%	0.35%
China	9.23%	1.78%	0.89%
India	7.27%	1.41%	0.70%
Mexico	9.09%	1.76%	0.87%
Russia	14.88%	2.81%	1.40%
Median, 43 Countries	16.83%	3.16%	1.57%

Notes: Data are from the 2006 World Input-Output Database for 43 countries. Gains from trade relative to autarky are computed using the formula $\lambda_{jj}^{1/\theta} - 1$, where λ_{jj} is 1 minus the import share.

Appendix C Partial Equilibrium Model

Notation Throughout this appendix, we let tildes denote percent deviations from steady state, e.g. $\tilde{v}_t = \ln v_t - \ln v = d \ln v_t = \frac{v_t - v}{v}$. Variables without subscripts denote steady state values.

For most of this appendix we suppress source and destination country as well as product subscripts for convenience. For clarity we provide an overview on the notation here:

- D_t denotes a demand shifter that varies by destination country and product, i.e. $D_t = D_{i,p,t}$
- c_t denotes domestic marginal costs of production that vary by source country and product, i.e. $c_t = c_{j,p,t}$
- τ_t denotes a tariff that varies by country-pair and product, i.e. $\tau_t = \tau_{i,j,p,t}$
- κ_t denotes iceberg non-tariff trade barriers that vary by country-pair and product, i.e. $\kappa_t = \kappa_{i,j,p,t}$
- ω_t denotes a taste shocks that varies by country-pair and product, i.e. $\omega_t = \omega_{i,j,p,t}$.

C.1 Model summary

The following system of equations characterizes the trade response to tariff shocks. The first set of equations is

$$p_t^x = p^x \left(c_t \kappa_t, \tau_t, \omega_t D_t\right), \tag{C.1}$$
$$q_t = q \left(p_t^x, \tau_t, \omega_t D_t\right), \tag{C.2}$$
$$\pi_t = \pi \left(c_t \kappa_t, \tau_t, \omega_t D_t\right), \tag{C.3}$$
$$X_t = q_t p_t^x n_t, \tag{C.4}$$

where p_t^x is the price of exports exclusive of tariffs, q_t is the quantity sold, π_t are flow profits, X_t is export revenue exclusive of tariffs, and n_t a generic mass. Let further v_t denote a generic value. The following dynamic system determines the evolution of v_t and n_t,

$$v_t = \frac{1}{1+r} \mathbb{E}_t \left[\pi \left(c_{t+1}\kappa_{t+1}, \tau_{t+1}, \omega_{t+1} D_{t+1}\right) + (1-\delta) v_{t+1}\right] \tag{C.5}$$
$$n_t = n_{t-1} (1-\delta) + G \left(v_{t-1}\right), \tag{C.6}$$

together with $\lim_{t\to\infty} \left(\frac{1-\delta}{1+r}\right)^t v_t = 0$, a given initial value for n_0, and stochastic processes for c_t, κ_t, τ_t, ω_t, and D_t, which are exogeneous in the partial equilibrium model.

We define the following constants

$$\eta_{q,p} := \frac{\partial \ln q}{\partial \ln p^x}, \; \eta_{q,\tau} := \frac{\partial \ln q}{\partial \ln \tau}, \; \eta_{p,\tau} := \frac{\partial \ln p^x}{\partial \ln \tau}, \; \eta_{\pi,\tau} := \frac{\partial \ln \pi}{\partial \ln \tau}, \tag{C.7}$$

and assume that $\eta_{q,p} < 0$, $\eta_{q,\tau} < 0$, and $\eta_{\pi,\tau} < 0$. We also define $\chi := \frac{g(v)v}{G(v)}$ for a function $G(.)$ introduced below, and $g = G'$.

C.2 Microfoundations

We next show that three different frameworks generate the above system of equations.

C.2.1 A dynamic Arkolakis (2010) model

This model is a dynamic extension of the Arkolakis (2010) market penetration framework, where the number of customers adjusts gradually. The model also shares features with Fitzgerald, Haller, and Yedid-Levi (2016) and others.

A single representative firm sells its good in the foreign location, earning profits $\Pi_t = n_t \pi \left(c_t \kappa_t, \tau_t, \omega_t D_t\right)$. Here, n_t denotes the mass of foreign consumers that the firm reaches in the foreign location. Further, $\pi \left(c_t \kappa_t, \tau_t, \omega_t D_t\right)$ denotes flow profits per unit mass of foreign consumers reached, and is a function of the exporter's costs c_t, non-tariff iceberg trade costs κ_t, tariffs τ_t, and the demand shifters $\omega_t D_t$.

The mass of foreign consumers available for the firm to sell to evolves according to the accumulation equation

$$n_{t+1} = n_t \left(1 - \delta\right) + a_t, \tag{C.8}$$

where a_t is the mass of newly added customers in the foreign country. Note that mass n_t is predetermined in the current period, so that adding new consumers this period only affects next period's mass of consumers n_{t+1}. We assume that adding a_t new customers requires a payment of $f(a_t)$, where $f' > 0$, $f'' > 0$, $\lim_{a \to 0} f'(a) = 0$, $\lim_{a \to \infty} f'(a) = \infty$, and that the existing mass of consumers already reached by the firm depreciates at rate δ.

The firm discounts at interest rate r and maximizes the present discounted value of future profits,

$$\max_{\{a_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t \left[n_t \pi \left(c_t \kappa_t, \tau_t, \omega_t D_t\right) - f\left(a_t\right)\right].$$

Denoting by v_t the multiplier on constraint (C.8), the current value Lagrangian is

$$\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t \left[n_t \pi \left(c_t \kappa_t, \tau_t, \omega_t D_t\right) - f\left(a_t\right) + v_t \left(n_t \left(1-\delta\right) + a_t - n_{t+1}\right)\right].$$

The first order necessary conditions are

$$\begin{aligned} f'\left(a_t\right) &= v_t, \\ v_t &= \frac{1}{1+r} \mathbb{E}_t \left[\pi \left(c_{t+1} \kappa_{t+1}, \tau_{t+1}, \omega_{t+1} D_{t+1}\right) + \left(1-\delta\right) v_{t+1}\right], \end{aligned}$$

and the transversality condition $\lim_{t \to \infty} \left(\frac{1}{1+r}\right)^t v_t n_t = 0$, which implies that $\lim_{t \to \infty} \left(\frac{1-\delta}{1+r}\right)^t v_t = 0$. The firm chooses its investment into accumulating new consumers such that the marginal benefit v_t equals the marginal cost $f'(a_t)$. The shadow value v_t, in turn, is the expected present value of profits generated by each consumer reached in the foreign market.

Note that the above problem is reminiscent of a standard investment problem with convex adjustment costs, except that flow profits are a linear function of n_t, the analogue of the capital stock. This linearity greatly improves the tractability of the problem and permits analytical solutions.

Letting $q_t = q\left(p_t^x, \tau_t, \omega_t D_t\right)$ denote foreign demand per unit mass of consumers, and letting $p_t^x = p^x\left(c_t \kappa_t, \tau_t\right)$ denote the price set by the representative firm, exports are $X_t = q_t p_t^x n_t$. After substituting out a_t, the accumulation equation (C.8) becomes

$$n_t = n_{t-1}\left(1-\delta\right) + \left(f'\right)^{-1}\left(v_{t-1}\right).$$

For $G \equiv \left(f'\right)^{-1}$, the model is described by the set of equations in Section C.1.

C.2.2 A dynamic Krugman (1980) model

We next present a dynamic partial equilibrium version of the Krugman (1980) model. The model also shares features with Costantini and Melitz (2007), Ruhl (2008), and many others.

There is a continuum of firms, and each exporting firm receives flow profits $\pi\left(c_t \kappa_t, \tau_t, \omega_t D_t\right)$ from exporting. Further, exporters exit the bilateral trade relationship with probability δ per period. The value of an exporting firm at the end of period t is

$$v_t = \frac{1}{1+r} E_t\left[\pi\left(c_{t+1}\kappa_{t+1}, \tau_{t+1}, \omega_{t+1} D_{t+1}\right) + \left(1-\delta\right) v_{t+1}\right],$$

where we assume that the value of a non-exporting firm is zero. We also require that $\lim_{t\to\infty}\left(\frac{1-\delta}{1+r}\right)^t v_t = 0$, which follows from the transversality condition of the firms' owner(s).

In every period, a unit mass of firms receives the opportunity to begin exporting to the foreign location. Each of these firms receive idiosyncratic i.i.d. sunk cost draw ξ_t^s, drawn from distribution G, and then decide whether to start exporting. Each firm solves

$$\max\left\{v_t - \xi_t^s, 0\right\},$$

so a firm enters if and only if $\xi_t^s \leq v_t$. Note that a firm entering this period begins to receive profits from exporting only in the next period. The mass of firms entering into exporting in period t is thus $G\left(v_t\right)$. The mass of exporting firms at the end of period t is denoted by n_t, and it evolves according to

$$n_{t+1} = n_t\left(1-\delta\right) + G\left(v_t\right).$$

Letting $q_t = q\left(p_t^x, \tau_t, \omega_t D_t\right)$ denote foreign demand per unit mass of firms, and letting $p_t^x = p^x\left(c_t \kappa_t, \tau_t\right)$ denote the price set by each firm, exports are $X_t = q_t p_t^x n_t$. It is clear that this model is nested by the set of equations in Section C.1.

C.2.3 A dynamic Melitz (2003) model

Consider a version of the Melitz (2003) model, with a two-stage entry problem. In the first stage of the entry problem, firms do not know their productivity of producing the exported good. Further, they pay a sunk cost to obtain the *right to export on a per-period basis*. Having paid this sunk cost, they learn their productivity and face the following static decision problem going forward: As long as the firm maintains its right to export on a per-period basis, it can pay a fixed cost to obtain the profit of exporting for one period.

First stage Let $\pi(c_t\kappa_t, \tau_t, \omega_t D_t)$ denote *expected* flow profits from exporting in stage one of the entry problem. The remainder of this stage is isomorphic to the dynamic Krugman (1980) model described above. Firms lose their right to export on a per-period basis with probability δ per period. The expected value of exporting at the end of period t is

$$v_t = \frac{1}{1+r} E_t\left[\pi\left(c_{t+1}\kappa_{t+1}, \tau_{t+1}, \omega_{t+1}D_{t+1}\right) + (1-\delta)\, v_{t+1}\right],$$

where we assume that the value of a non-exporting firm is zero. We also require that $\lim_{t\to\infty}\left(\frac{1-\delta}{1+r}\right)^t v_t = 0$, which follows from the transversality condition of the firms' owner(s).

In every period, a unit mass of firms faces the first stage of the entry problem. Each of these firms receives an idiosyncratic i.i.d. sunk cost ξ_t^s draw from distribution G, and then decides whether to enter into the second stage. Each firm solves

$$\max\left\{v_t - \xi_t^s, 0\right\},$$

so a firm enters if and only if $\xi_t^s \leq v_t$. Note that a firm entering this period faces the second stage of the entry problem only in the next period. The mass of firms entering into the second stage in period t is $G(v_t)$. The mass of firms with the right to export on a per-period basis is denoted by n_t, and evolves according to

$$n_{t+1} = n_t(1-\delta) + G(v_t).$$

Foreign consumer We assume that foreign demand takes the form $Q_t = (P_t^c)^{-\sigma}\omega_t D_t$, where $P_t^c = \tau_t P_t^x$ is the price the consumer pays for the export bundle, so that $Q_t = (\tau_t P_t^x)^{-\sigma}\omega_t D_t$. The quantity aggregate of firm-level exports Q_t takes the CES form

$$Q_t = \left(\int_{\iota\in\mathcal{I}_t} q_t(\iota)^{\frac{\sigma-1}{\sigma}} d\iota\right)^{\frac{\sigma}{\sigma-1}}, \tag{C.9}$$

where ι indexes exporting firms and $\mathcal{I}_t$ is the set of exporting firms. Profit maximization implies that

$$q_t(\iota) = Q_t\left(\frac{p_t^x(\iota)}{P_t^x}\right)^{-\sigma}, \tag{C.10}$$

where

$$P_t^x = \left(\int_{j\in J_t} \left(p_t^x(\iota)\right)^{1-\sigma} d\iota\right)^{\frac{1}{1-\sigma}}. \tag{C.11}$$

Measured exports exclusive of tariffs are $X_t = Q_t P_t^x$.

Second stage Once a firm has paid the sunk entry cost, it draws its productivity φ from distribution F, which we assume to be independent of the sunk cost draw ξ_t^s. A firm's marginal costs are $\frac{\kappa_t c_t}{\varphi}$. Each firm faces demand function (C.10). Profit maximization implies that

$$p_t^x(\iota) = \frac{\sigma}{\sigma-1}\frac{\kappa_t c_t}{\varphi(\iota)},$$

and yields flow profits from exporting

$$\begin{aligned}\pi_t(\iota) &= q_t(\iota)\left(p_t^x(\iota) - \frac{\kappa_t c_t}{\varphi(\iota)}\right) - \xi \\ &= \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{\kappa_t c_t}{\varphi(\iota)}\right)^{1-\sigma} Q_t (P_t^x)^\sigma - \xi,\end{aligned}$$

where ξ denotes the per-period fixed cost of exporting, which is common across firms.

A firm exports in period t if $\pi_t(\iota) \geq 0$, and the marginal firm has productivity

$$\varphi_t^m = \frac{\sigma}{\sigma-1}\kappa_t c_t \left(\frac{\sigma\xi}{Q_t (P_t^x)^\sigma}\right)^{\frac{1}{\sigma-1}}.$$

Note that Q_t and P_t^x depend on τ_t and hence changes in tariffs will affect the composition of firms that export in a given period.

Following Melitz (2003), we write the price index (C.11) as

$$\begin{aligned}P_t^x &= \left(\int_{\varphi_t^m}^{\infty} (p_t^x(\varphi))^{1-\sigma} n_t dF(\varphi)\right)^{\frac{1}{1-\sigma}} \\ &= n_t^{\frac{1}{1-\sigma}} \frac{\sigma}{\sigma-1}\kappa_t c_t \left(\int_{\varphi_t^m}^{\infty} \varphi^{\sigma-1} dF(\varphi)\right)^{\frac{1}{1-\sigma}} \\ &= n_t^{\frac{1}{1-\sigma}} \frac{\sigma}{\sigma-1}\frac{\kappa_t c_t}{\tilde{\varphi}_t}\end{aligned}$$

where

$$\tilde{\varphi}_t = \left(\int_{\varphi_t^m}^{\infty} \varphi^{\sigma-1} dF(\varphi)\right)^{\frac{1}{\sigma-1}}. \tag{C.12}$$

Note that $\tilde{\varphi}_t$ denotes an *aggregate* productivity measure of exporting firms, and not an *average*.

Now letting

$$p_t^x(\tilde{\varphi}_t) = \frac{\sigma}{\sigma-1}\frac{\kappa_t c_t}{\tilde{\varphi}_t}, \tag{C.13}$$

we have

$$P_t^x = n_t^{\frac{1}{1-\sigma}} p_t^x(\tilde{\varphi}_t).$$

Again following Melitz (2003), and noting that $q_t(\varphi) = Q_t\left(\frac{p_t^x(\varphi)}{P_t^x}\right)^{-\sigma}$ and

$$q_t(\tilde{\varphi}_t) = Q_t\left(\frac{p_t^x(\tilde{\varphi}_t)}{P_t^x}\right)^{-\sigma}, \tag{C.14}$$

we have that $q_t(\varphi) = \left(\frac{\varphi_t}{\tilde{\varphi}_t}\right)^{\sigma} q(\tilde{\varphi}_t)$. We can then write the quantity index (C.9) as

$$\begin{aligned} Q_t &= \left(\int_{\varphi_t^m}^{\infty} q_t(\varphi)^{\frac{\sigma-1}{\sigma}} n_t dF(\varphi)\right)^{\frac{\sigma}{\sigma-1}} \\ &= n_t^{\frac{\sigma}{\sigma-1}} q_t(\tilde{\varphi}_t). \end{aligned}$$

Now the total value of exports is

$$\begin{aligned} X_t &= Q_t P_t^x \\ &= n_t^{\frac{\sigma}{\sigma-1}} q(\tilde{\varphi}_t) n_t^{\frac{1}{1-\sigma}} p^x(\tilde{\varphi}_t) \\ &= n_t q_t(\tilde{\varphi}_t) p_t^x(\tilde{\varphi}_t), \end{aligned}$$

where $\tilde{\varphi}_t$, $p_t^x(\tilde{\varphi}_t)$, and $q_t(\tilde{\varphi}_t)$ are defined in equations (C.12), (C.13), and (C.14).

Lastly, expected profits can be written as

$$\pi_t = \frac{1}{\sigma} Q_t (P_t^x)^{\sigma} \left(\frac{\sigma}{\sigma-1}\frac{\kappa_t c_t}{\tilde{\varphi}_t}\right)^{1-\sigma} - \xi\left(1 - F(\varphi_t^m)\right).$$

Since our assumptions on foreign demand imply that $Q_t (P_t^x)^{\sigma} = (\tau_t)^{-\sigma} \omega_t D_t$, we can write

$$\begin{aligned} p_t^x(\tilde{\varphi}_t) &= \frac{\sigma}{\sigma-1}\frac{\kappa_t c_t}{\tilde{\varphi}_t} \\ q_t(\tilde{\varphi}_t) &= (p_t^x(\tilde{\varphi}_t))^{-\sigma} (\tau_t)^{-\sigma} \omega_t D_t \\ \pi_t &= \frac{1}{\sigma}(\tau_t)^{-\sigma} \omega_t D_t \left(\frac{\sigma}{\sigma-1}\frac{\kappa_t c_t}{\tilde{\varphi}_t}\right)^{1-\sigma} - \xi\left(1 - F(\varphi_t^m)\right) \end{aligned}$$

where $\tilde{\varphi}_t$ is given by equation (C.12) and

$$\varphi_t^m = \frac{\sigma}{\sigma-1}\kappa_t c_t \left(\frac{\sigma\xi}{(\tau_t)^{-\sigma}\omega_t D_t}\right)^{\frac{1}{\sigma-1}}.$$

It is now easy to see that the above functions take the forms assumed in equations (C.1)-(C.4).

While the exact values of elasticities (C.7) depend on the distribution F, it is always true that $\frac{\partial \ln \varphi_t^m}{\partial \ln \tau_t} = \frac{\sigma}{\sigma-1} > 0$, $\frac{\partial \ln \tilde{\varphi}_t}{\partial \ln \tau_t} < 0$, and hence $\frac{\partial \ln p_t^x}{\partial \ln \tau_t} = -\frac{\partial \ln \tilde{\varphi}_t}{\partial \ln \tau_t} > 0$. Further, $\frac{\partial \ln q_t}{\partial \ln \tau_t} = -\sigma$.

C.3 Model solution

Global solution Solving equation (C.5) forward gives, after imposing the transversality condition,

$$v_t = \frac{1}{1+r}\mathbb{E}_t\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\pi_{t+\ell+1}\right].$$

Further, solving equation (C.6) backwards gives

$$n_t = \sum_{k=0}^{t-1}(1-\delta)^k G(v_{t-1-k}) + (1-\delta)^t n_0.$$

The model solution is unique: for any sequence of $\pi_{t+\ell+1}$'s, the first equation yields a unique v_t, and for any sequence of v_t's, the second equation yields a unique n_t.

Nonstochastic steady state Suppose all exogenous driving forces are constant so that $c_t = c$, $\kappa_t = \kappa$, $\tau_t = \tau$, $\omega_t = \omega$ and $D_t = D$. Then $\pi_t = \pi$, and v_t immediately collapses to

$$v = \frac{\pi}{r+\delta}.$$

Further, n_t converges to

$$n = \frac{G(v)}{\delta}.$$

These two equations characterize the non-stochastic steady state.

Long-run trade elasticity The long-run trade elasticity is

$$\begin{aligned}\frac{d\ln X}{d\ln\tau} &= \frac{d\ln q}{d\ln\tau} + \frac{d\ln p^x}{d\ln\tau} + \frac{d\ln n}{d\ln\tau}\\ &= \varepsilon^0 + \frac{d\ln n}{d\ln\tau},\end{aligned}$$

where

$$\frac{d\ln n}{d\ln\tau} = \frac{d\ln n}{d\ln v}\frac{d\ln v}{d\ln\tau} = \chi\frac{d\ln\pi}{d\ln\tau} = \chi\eta_{\pi,\tau},$$

and

$$\chi := \frac{d\ln n}{d\ln v} = \frac{d\ln G(v)}{d\ln v} = \frac{g(v)\,v}{G(v)}.$$

Monotone convergence If $c_t = c$, $\kappa_t = \kappa$, $\tau_t = \tau$, $\omega_t = \omega$ and $D_t = D$, then $v_t = v = \frac{\pi}{r+\delta}$. It then follows from equation (C.6) above that

$$\begin{aligned}n_t - n &= (1-\delta)(n_{t-1}-n) + G(v) - \delta n\\ &= (1-\delta)(n_{t-1}-n),\end{aligned}$$

so convergence is monotone.

Linearized economy We characterize all impulse response functions and trade elasticities up to a first order approximation. Letting tildes denote percent deviations from steady state, e.g. $\tilde{v}_t = \ln v_t - \ln v = d\ln v_t = \frac{v_t - v}{v}$, these are

$$\tilde{v}_t = \mathbb{E}_t\left[\frac{\delta+r}{1+r}\tilde{\pi}_{t+1} + \frac{1-\delta}{1+r}\tilde{v}_{t+1}\right],$$
$$\tilde{n}_t = \tilde{n}_{t-1}(1-\delta) + \delta\chi\tilde{v}_{t-1}, \tag{C.15}$$

in recursive form and

$$\tilde{v}_t = \frac{\delta+r}{1+r}\mathbb{E}_t\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\tilde{\pi}_{t+\ell+1}\right], \tag{C.16}$$
$$\tilde{n}_t = \delta\chi\sum_{k=0}^{t-1}(1-\delta)^{t-1-k}\tilde{v}_k + (1-\delta)^t\tilde{n}_0,$$

when solved forwards and backwards, respectively.

Further, the static model block (C.1)-(C.4) takes the form

$$\tilde{p}^x_t = \eta_{p,c}(\tilde{c}_t + \tilde{\kappa}_t) + \eta_{p,\tau}\tilde{\tau}_t + \eta_{p,D}\left(\tilde{\omega}_t + \tilde{D}_t\right), \tag{C.17}$$
$$\tilde{q}_t = \eta_{q,p}\tilde{p}^x_t + \eta_{q,\tau}\tilde{\tau}_t + \eta_{q,D}\left(\tilde{\omega}_t + \tilde{D}_t\right), \tag{C.18}$$
$$\tilde{\pi}_t = \eta_{\pi,c}(\tilde{c}_t + \tilde{\kappa}_t) + \eta_{\pi,\tau}\tilde{\tau}_t + \eta_{\pi,D}\left(\tilde{\omega}_t + \tilde{D}_t\right), \tag{C.19}$$
$$\tilde{X}_t = \tilde{q}_t + \tilde{p}^x_t + \tilde{n}_t,$$

where, analogously to (7), $\eta_{a,b} := \frac{\partial \ln a}{\partial \ln b}$ for any a, b.

C.4 Proofs of propositions and examples

C.4.1 Proof of Proposition 1

Proposition 1. *Consider an arbitrary evolution of tariffs* $\left\{\frac{d\ln\tau_{t_0+\ell}}{d\ln\tau_{t_0}}\right\}_{\ell=1}^{\infty}$ *after the shock at* t_0. *The impulse response function of* $\ln n_t$ *at horizon* $h = 0, 1, 2, \ldots$ *is*

$$\frac{d\ln n_{t_0+h}}{d\ln\tau_{t_0}} = \chi\eta_{\pi,\tau}\frac{\delta+r}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t_0+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\frac{d\ln\tau_{t_0+k+\ell+1}}{d\ln\tau_{t_0}}\right].$$

Proof. Combining equation (C.16) as of time t_0+k with the fact that $\tilde{\pi}_t = \eta_{\pi,\tau}\tilde{\tau}_t$ in the version of the model with tariff shocks only (see C.19) gives

$$\tilde{v}_{t_0+k} = \eta_{\pi,\tau}\frac{\delta+r}{1+r}\mathbb{E}_{t_0+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\tilde{\tau}_{t_0+k+\ell+1}\right]. \tag{C.20}$$

Next take equation (C.15) at time t_0+h and solve it backwards until period t_0. This gives

$$\tilde{n}_{t_0+h} = \delta\chi \sum_{k=0}^{h-1} (1-\delta)^{h-1-k}\, \tilde{v}_{t_0+k} + (1-\delta)^h\, \tilde{n}_{t_0} \tag{C.21}$$

Now plugging (C.20) into (C.21) gives

$$\tilde{n}_{t_0+h} = \eta_{\pi,\tau}\chi \frac{\delta+r}{1+r}\delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k}\, \mathbb{E}_{t_0+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell} \tilde{\tau}_{t_0+k+\ell+1}\right] + (1-\delta)^h\, \tilde{n}_{t_0}.$$

Lastly, replace $\tilde{n}_{t_0+h}$ with $d\ln n_{t_0+h}$, etc., differentiate with respect to $d\ln\tau_{t_0}$, and note that $\frac{d\ln n_{t_0}}{d\ln \tau_{t_0}} = 0$.

□

C.4.2 Proof of Proposition 2

Proposition 2. *If* $\lim_{h\to\infty} \frac{d\ln\tau_{t_0+h}}{d\ln\tau_{t_0}} \neq 0$ *and is finite, then* $\lim_{h\to\infty}\varepsilon^h = \varepsilon$*.*

Proof. We first show that $\{\tilde{v}_{t_0+h}\}_{h=0}^{\infty}$ converges to $\eta_{\pi,\tau}\tilde{\tau}$. Fix an arbitrary $\psi > 0$. Since $\{\tilde{\tau}_{t_0+h}\}_{h=0}^{\infty}$ converges to $\tilde{\tau}$, there exists a h_ψ such that for $\forall h \geq h_\psi : |\tilde{\tau}_{t_0+h} - \tilde{\tau}| < \frac{\psi}{|\eta_{\pi,\tau}|}$. Next note that

$$\tilde{v}_{t+h} - \eta_{\pi,\tau}\tilde{\tau} = \frac{\delta+r}{1+r}\mathbb{E}_{t+h}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell} \eta_{\pi,\tau}\left(\tilde{\tau}_{t+h+\ell+1} - \tilde{\tau}\right)\right].$$

Then, for $h \geq h_\psi$, and using Jensen's and the triangle inequality,

$$\begin{aligned} |\tilde{v}_{t+h} - \eta_{\pi,\tau}\tilde{\tau}| &\leq \frac{\delta+r}{1+r}\mathbb{E}_{t+h}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell} \left|\eta_{\pi,\tau}\left(\tilde{\tau}_{t+h+\ell+1} - \tilde{\tau}\right)\right|\right] \\ &< \frac{\delta+r}{1+r}\mathbb{E}_{t+h}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell} \psi\right] = \psi, \end{aligned}$$

and hence $\{\tilde{v}_{t_0+h}\}_{h=0}^{\infty}$ converges to $\eta_{\pi,\tau}\tilde{\tau}$.

We next show that $\{\tilde{n}_{t_0+h}\}$ converges to $\chi\eta_{\pi,\tau}\tilde{\tau}$. Fix an arbitrary $\psi > 0$. Since $\{\tilde{v}_{t_0+h}\}_{h=0}^{\infty}$ converges to $\eta_{\pi,\tau}\tilde{\tau}$, there exists a h_ψ such that for $\forall h \geq h_\psi : |\tilde{v}_{t_0+h} - \eta_{\pi,\tau}\tilde{\tau}| < \frac{\psi}{2\chi}$. Next note that for $h > h_\psi$,

$$\begin{aligned} \tilde{n}_{t_0+h} &= \delta\chi \sum_{k=0}^{h-1} (1-\delta)^{h-1-k}\, \tilde{v}_{t_0+k} + (1-\delta)^h\, \tilde{n}_{t_0} \\ &= \delta\chi \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k}\, \tilde{v}_{t_0+k} + \delta\chi\,(1-\delta_\psi)^{h-h_\psi} \sum_{k=0}^{h_\psi-1} (1-\delta)^{h_\psi-1-k}\, \tilde{v}_{t_0+k} + (1-\delta)^h\, \tilde{n}_{t_0}. \end{aligned}$$

Then, for $h > h_\psi$,

$$
\begin{aligned}
\tilde{n}_{t_0+h} - \chi\eta_{\pi,\tau}\tilde{\tau} =& \delta\chi \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} \left(\tilde{v}_{t_0+k} - \eta_{\pi,\tau}\tilde{\tau} + \eta_{\pi,\tau}\tilde{\tau}\right) - \chi\eta_{\pi,\tau}\tilde{\tau} \\
&+ \delta\chi \left(1-\delta_\psi\right)^{h-h_\psi} \sum_{k=0}^{h_\psi-1} (1-\delta)^{h_\psi-1-k} \tilde{v}_{t_0+k} + (1-\delta)^h \tilde{n}_{t_0} \\
=& \delta\chi \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} \left(\tilde{v}_{t_0+k} - \eta_{\pi,\tau}\tilde{\tau}\right) + \delta\chi\eta_{\pi,\tau}\tilde{\tau} \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} - \chi\eta_{\pi,\tau}\tilde{\tau} \\
&+ \delta\chi \left(1-\delta_\psi\right)^{h-h_\psi} \sum_{k=0}^{h_\psi-1} (1-\delta)^{h_\psi-1-k} \tilde{v}_{t_0+k} + (1-\delta)^h \tilde{n}_{t_0} \\
=& \delta\chi \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} \left(\tilde{v}_{t_0+k} - \eta_{\pi,\tau}\tilde{\tau}\right) \\
&- \chi\eta_{\pi,\tau}\tilde{\tau} (1-\delta)^{h-h_\psi} + \delta\chi \left(1-\delta_\psi\right)^{h-h_\psi} \sum_{k=0}^{h_\psi-1} (1-\delta)^{h_\psi-1-k} \tilde{v}_{t_0+k} + (1-\delta)^h \tilde{n}_{t_0},
\end{aligned}
$$

where we used that $\sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} = \frac{1-(1-\delta)^{h-h_\psi}}{\delta}$. Next note that

$$
\begin{aligned}
\left| \delta\chi \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} \left(\tilde{v}_{t_0+k} - \eta_{\pi,\tau}\tilde{\tau}\right) \right| &\leq \delta\chi \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} \left|\tilde{v}_{t_0+k} - \eta_{\pi,\tau}\tilde{\tau}\right| \\
&< \delta\chi \sum_{k=h_\psi}^{h-1} (1-\delta)^{h-1-k} \frac{\psi}{2\chi} = \frac{\psi}{2} \left[1 - (1-\delta)^{h-h_\psi}\right].
\end{aligned}
$$

Hence,

$$
\begin{aligned}
\left|\tilde{n}_{t_0+h} - \chi\eta_{\pi,\tau}\tilde{\tau}\right| <& \frac{\psi}{2} \left[1 - (1-\delta)^{h-h_\psi}\right] + (1-\delta)^{h-h_\psi} \left|\chi\eta_{\pi,\tau}\tilde{\tau}\right| \\
&+ \left(1-\delta_\psi\right)^{h-h_\psi} \left| \delta\chi \sum_{k=0}^{h_\psi-1} (1-\delta)^{h_\psi-1-k} \tilde{v}_{t_0+k} \right| + (1-\delta)^h \left|\tilde{n}_{t_0}\right|.
\end{aligned}
$$

Now choosing $h_\psi^* > h_\psi$ such that for all $h > h_\psi^*$ the last three terms are smaller than $\frac{\psi}{2}$, implies that $\tilde{n}_{t_0+h}$ converges to $\chi\eta_{\pi,\tau}\tilde{\tau}$.

Lastly note that $\tilde{X}_{t_0+h} = \varepsilon^0\tilde{\tau}_{t_0+h} + \tilde{n}_{t_0+h}$, and hence $\lim_{h\to\infty} \tilde{X}_{t_0+h} = \varepsilon^0\tilde{\tau} + \chi\eta_{\pi,\tau}\tilde{\tau} = \varepsilon\tilde{\tau}$. Since $\tilde{\tau} \neq 0$, $\lim_{h\to\infty} \varepsilon^h = \lim_{h\to\infty} \frac{\tilde{X}_{t_0+h}}{\tilde{\tau}_{t_0+h}} = \varepsilon$.

□

C.4.3 Details on Example 1

Plug $\Delta \ln \tau_{>t_0}$ into equation (16). This gives

$$\begin{aligned}\frac{d \ln n_{t_0+h}}{d \ln \tau_{t_0}} &= \chi \eta_{\pi,\tau} \Delta \ln \tau_{>t_0} \delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \\ &= \chi \eta_{\pi,\tau} \left[1-(1-\delta)^h\right] \Delta \ln \tau_{>t_0}.\end{aligned}$$

The claim now follows immediately.

C.4.4 Details on Example 2

Tariffs follow a first or autoregressive process with autoregressive root ρ. Then

$$\mathbb{E}_{t_0+k}\left[\frac{d \ln \tau_{t_0+k+\ell+1}}{d \ln \tau_{t_0}}\right] = \rho^{\ell+k+1}.$$

Plugging this expression into (16) gives

$$\begin{aligned}\frac{d \ln n_{t_0+h}}{d \ln \tau_{t_0}} &= \chi \eta_{\pi,\tau} \frac{\delta+r}{1+r} \delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \sum_{\ell=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^{\ell} \rho^{\ell+k+1} \\ &= \chi \eta_{\pi,\tau} \frac{\delta+r}{1+r} \delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} (\rho)^{k+1} \left[\sum_{\ell=0}^{\infty} \left(\frac{1-\delta}{1+r}\rho\right)^{\ell}\right] \\ &= \chi \eta_{\pi,\tau} \frac{\delta+r}{1+r-(1-\delta)\rho} \delta \rho^h \sum_{k=0}^{h-1} \left(\frac{1-\delta}{\rho}\right)^{h-1-k} \\ &= \chi \eta_{\pi,\tau} \frac{\delta+r}{1+r-(1-\delta)\rho} \delta \rho^h \frac{1-\left(\frac{1-\delta}{\rho}\right)^h}{1-\frac{1-\delta}{\rho}}.\end{aligned}$$

Since

$$\frac{\frac{d \ln n_{t_0+h}}{d \ln \tau_{t_0}}}{\frac{d \ln \tau_{t_0+h}}{d \ln \tau_{t_0}}} = \chi \eta_{\pi,\tau} \frac{(\delta+r)\delta}{\left[1+r-(1-\delta)\rho\right]\left(1-\frac{1-\delta}{\rho}\right)} \left(1-\left(\frac{1-\delta}{\rho}\right)^h\right),$$

the claim follows immediately.

C.4.5 Proof of Proposition 3

Proposition 3. *The model delivers estimating equation* (2)*, where*

$$\beta_X^h = \chi \eta_{\pi,\tau} \frac{r+\delta}{1+r} \delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \sum_{\ell=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^{\ell} \beta_\tau^{k+\ell+1} + \varepsilon^0 \beta_\tau^h.$$

β_τ^h is defined as the regression coefficient of $\Delta_h \ln \tau_{i,j,p,t}$ on $\Delta_0 \ln \tau_{i,j,p,t}$ in the population, and can be estimated from equation (3)*.*

The fixed effects $\delta_{j,p,t}^{s,X,h}$ and $\delta_{i,p,t}^{d,X,h}$ capture a weighted sum of past, present, and expected future changes in interest rates, demand, the cost of production, the cost of entry, and non-tariff trade barriers that vary at the exporter-product-time (j,p,t) and importer-product-time (i,p,t) level, respectively, in model extensions in which these vary over time. The error term includes past, present, and expected future time-varying importer-exporter-product-specific demand shocks and non-tariff trade barriers, as well as the initial state.

Proof. We consider a model extension given by equations (C.1) through (C.4) together with

$$
\begin{aligned}
v_t &= \frac{1}{1+r_t} \mathbb{E}_t \left[\pi_{t+1} + (1-\delta) v_{t+1}\right], \\
n_t &= n_{t-1} (1-\delta) + G\left(\frac{v_{t-1}}{c_{t-1}^e}\right).
\end{aligned}
$$

Relative to the version of the model stated above, the interest rate r_t now exogenously varies with time, and we allow for exogenous variation in the cost of entry c_t^e. We assume that the interest rate is specific to the source country, so that $r_t = r_{j,t}$, and that the time-varying component of entry cost varies by source country and product, that is, $c_t^e = c_{j,p,t}^e$. Initially, we suppress these subscripts. The linearized versions of these two equations are

$$
\tilde{v}_t = \frac{r+\delta}{1+r} \mathbb{E}_t \left[\tilde{\pi}_{t+1}\right] + \frac{1-\delta}{1+r} \mathbb{E}_t \left[\tilde{v}_{t+1}\right] - \frac{1}{1+r} dr_t, \tag{C.22}
$$

$$
\tilde{n}_t = (1-\delta) \tilde{n}_{t-1} + \delta \chi \left(\tilde{v}_{t-1} - \tilde{c}_{t-1}^e\right). \tag{C.23}
$$

In equation (C.22) dr_t denotes the absolute deviation of the interest rate from its steady state value, that is $dr_t = r_t - r$.

Using equations (C.18) and (C.17), and the definition of $\varepsilon^0 = (1+\eta_{q,p}) \eta_{p,\tau} + \eta_{q,\tau}$ (equation 12), we have

$$
\begin{aligned}
\tilde{q}_{t+h} - \tilde{q}_{t-1} + \tilde{p}_{t+h}^x - \tilde{p}_{t-1}^x = {} & \varepsilon^0 \left(\tilde{\tau}_{t+h} - \tilde{\tau}_{t-1}\right) \\
& + (1+\eta_{q,p}) \eta_{p,c} \left(\tilde{\kappa}_{t+h} - \tilde{\kappa}_{t-1}\right) + \left[(1+\eta_{q,p}) \eta_{p,D} + \eta_{q,D}\right] \left(\tilde{\omega}_{t+h} - \tilde{\omega}_{t-1}\right) \\
& + (1+\eta_{q,p}) \eta_{p,c} \left(\tilde{c}_{t+h} - \tilde{c}_{t-1}\right) \\
& + \left[(1+\eta_{q,p}) \eta_{p,D} + \eta_{q,D}\right] \left(\tilde{D}_{t+h} - \tilde{D}_{t-1}\right).
\end{aligned}
$$

Next, note that solving (C.22) forward gives

$$
\tilde{v}_{t+k} = \sum_{\ell=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^{\ell} \left(\frac{r+\delta}{1+r} \mathbb{E}_{t+k} \left[\tilde{\pi}_{t+k+\ell+1}\right] - \frac{1}{1+r} \mathbb{E}_{t+k} \left[dr_{t+k+\ell}\right]\right),
$$

and solving (C.23) backwards gives

$$\tilde{n}_{t+h}=(1-\delta)^{h}\,\tilde{n}_{t}+\delta\chi\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\left(\tilde{v}_{t+k}-\tilde{c}^{e}_{t+k}\right).$$

Combining these two equations yields

$$\begin{aligned}\tilde{n}_{t+h}-\tilde{n}_{t-1}=&\,\chi\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\left(\tilde{\pi}_{t+k+\ell+1}-\tilde{\pi}_{t-1}\right)\right]\\&-\frac{1}{1+r}\delta\chi\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}dr_{t+k+\ell}\right]\\&-\delta\chi\left[\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\tilde{c}^{e}_{t+k}\right]+\chi\left[1-(1-\delta)^{h}\right]\tilde{\pi}_{t-1}+(1-\delta)^{h}\,\tilde{n}_{t}-\tilde{n}_{t-1}.\end{aligned}$$

From (C.19) we obtain

$$\begin{aligned}\tilde{\pi}_{t+k+\ell+1}-\tilde{\pi}_{t-1}=&\,\eta_{\pi,c}\left(\tilde{c}_{t+k+\ell+1}-\tilde{c}_{t-1}\right)+\eta_{\pi,c}\left(\tilde{\kappa}_{t+k+\ell+1}-\tilde{\kappa}_{t-1}\right)+\eta_{\pi,\tau}\left(\tilde{\tau}_{t+k+\ell+1}-\tilde{\tau}_{t-1}\right)\\&+\eta_{\pi,D}\left(\tilde{\omega}_{t+k+\ell+1}-\tilde{\omega}_{t-1}\right)+\eta_{\pi,D}\left(\tilde{D}_{t+k+\ell+1}-\tilde{D}_{t-1}\right).\end{aligned}$$

Now putting the pieces together, and adding the subscripts back in, we have that

$$\begin{aligned}\Delta_{h}\ln X_{i,j,p,t}=&\,\varepsilon^{0}\Delta_{h}\ln\tau_{i,j,p,t}+\eta_{\pi,\tau}\chi\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\Delta_{k+\ell+1}\ln\tau_{i,j,p,t}\right]\\&+\delta^{s,X,h}_{j,p,t}+\delta^{d,X,h}_{i,p,t}+u^{X,h}_{i,j,p,t},\end{aligned}$$

where we used the notation that for a generic variable x_t, $\Delta_h x_t=x_{t+h}-x_{t-1}$, and

$$\begin{aligned}\delta^{s,X,h}_{j,p,t}:=&\,\left(1+\eta_{q,p}\right)\eta_{p,c}\left(\tilde{c}_{j,p,t+h}-\tilde{c}_{j,p,t-1}\right)\\&+\eta_{\pi,c}\chi\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\left(\tilde{c}_{j,p,t+k+\ell+1}-\tilde{c}_{j,p,t-1}\right)\right]\\&-\frac{1}{1+r}\delta\chi\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}dr_{j,p,t+k+\ell}\right]\\&-\delta\chi\left[\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\tilde{c}^{e}_{j,p,t+k}\right],\end{aligned}\tag{C.24}$$

$$\delta^{d,X,h}_{i,p,t} := \left[(1+\eta_{q,p})\,\eta_{p,D}+\eta_{q,D}\right]\left(\tilde{D}_{i,p,t+h}-\tilde{D}_{i,p,t-1}\right)$$
$$+\,\eta_{\pi,D}\chi\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\left(\tilde{D}_{i,p,t+k+\ell+1}-\tilde{D}_{i,p,t-1}\right)\right], \quad \text{(C.25)}$$

$$u^{X,h}_{i,j,p,t} := (1+\eta_{q,p})\,\eta_{p,c}\left(\tilde{\kappa}_{i,j,p,t+h}-\tilde{\kappa}_{i,j,p,t-1}\right)$$
$$+\,\eta_{\pi,c}\chi\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\left(\tilde{\kappa}_{i,j,p,t+k+\ell+1}-\tilde{\kappa}_{i,j,p,t-1}\right)\right]$$
$$+\left[(1+\eta_{q,p})\,\eta_{p,D}+\eta_{q,D}\right]\left(\tilde{\omega}_{i,j,p,t+h}-\tilde{\omega}_{i,j,p,t-1}\right)$$
$$+\,\eta_{\pi,D}\chi\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\left(\tilde{\omega}_{i,j,p,t+k+\ell+1}-\tilde{\omega}_{i,j,p,t-1}\right)\right]$$
$$+\,\chi\left[1-(1-\delta)^{h}\right]\tilde{\pi}_{i,j,p,t-1}+(1-\delta)^{h}\,\tilde{n}_{i,j,p,t}-\tilde{n}_{i,j,p,t-1}. \quad \text{(C.26)}$$

Next define the regression coefficient of $\Delta_h \ln \tau_{i,j,p,t}$ on $\Delta_0 \ln \tau_{i,j,p,t}$ as β^h_τ in the population, where we assume that $\Delta_0 \ln \tau_{i,j,p,t}$ is an exogenous tariff shock. Clearly, β^h_τ can be estimated from equation (3). Then the estimating equation becomes

$$\Delta_h \ln X_{i,j,p,t} = \beta^h_X \Delta_0 \ln \tau_{i,j,p,t} + \delta^{d,X,h}_{i,p,t} + \delta^{s,X,h}_{j,p,t} + u^{X,h}_{i,j,p,t}.$$

where

$$\beta^h_X = \eta_{\pi,\tau}\chi\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\beta^{k+\ell+1}_\tau + \varepsilon^0\beta^h_\tau.$$

Note that β^h_τ is a constant for all $h = 0, 1, ...$, so the expectation drops out.

As equation (C.24) shows, the source-product-time fixed effects $\delta^{s,X,h}_{j,p,t}$ absorb variation in lagged, current, and future cost of production $c_{j,p,t}$, interest rates $r_{j,t}$, and the cost of entry $c^e_{j,p,t}$. Equation (C.25) shows that the destination-product-time fixed effects $\delta^{d,X,h}_{i,p,t}$ absorb variation in lagged, current, and future demand $D_{i,p,t}$. Lastly, equation (C.26) shows that the error term $u^{X,h}_{i,j,p,t}$ includes variation in lagged, current, and future bilateral and product-specific demand shocks $\omega_{i,j,p,t}$ and iceberg non-tariff trade barriers $\kappa_{i,j,p,t}$, as well as initial conditions.

□

C.5 Estimation in long differences

Proposition C.1. *(Part 1) Estimation as a horizon-h difference does generally not identify the horizon-h trade elasticity.*

(Part 2) If tariffs follow a random walk, a regression of $\Delta_h \ln X_t$ on $\Delta_h \ln \tau_t$ identifies the simple average of horizon-0 to horizon-h trade elasticities.

Proof. Since the first part of the proposition follows from the second part, we prove the second part.

Tariffs follow a random walk,

$$\tilde{\tau}_t = \tilde{\tau}_{t-1} + \sigma_u u_t^\tau,$$

where u_t^τ is white noise with unit variance, and σ_u denotes the standard deviation of the innovation to tariffs. Then

$$\tilde{\tau}_{t+k} - \tilde{\tau}_{t-1} = \sigma_u \sum_{j=0}^{k} u_{t+j}^\tau.$$

Consider the projection of $\tilde{\tau}_{t+k} - \tilde{\tau}_{t-1}$ on $\tilde{\tau}_{t+h} - \tilde{\tau}_{t-1}$ (i.e. the OLS estimator),

$$\frac{\mathbb{C}ov\left[\tilde{\tau}_{t+k} - \tilde{\tau}_{t-1}, \tilde{\tau}_{t+h} - \tilde{\tau}_{t-1}\right]}{\mathbb{V}\left[\tilde{\tau}_{t+h} - \tilde{\tau}_{t-1}\right]} = \frac{\mathbb{C}ov\left[\sum_{j=0}^{k} u_{t+k}^\tau, \sum_{j=0}^{h} u_{t+k}^\tau\right]}{\mathbb{V}\left[\sum_{j=0}^{h} u_{t+k}^\tau\right]} = \frac{k+1}{h+1}. \tag{C.27}$$

Next note that

$$\begin{aligned}\tilde{n}_{t+h} - \tilde{n}_{t-1} =& \chi \frac{\delta + r}{1+r} \delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^{\ell} (\tilde{\pi}_{t+k+\ell+1} - \tilde{\pi}_{t-1})\right] \\ &+ \chi \tilde{\pi}_{t-1}\left[1 - (1-\delta)^h\right] + \tilde{n}_t (1-\delta)^h - \tilde{n}_{t-1},\end{aligned}$$

which implies, together with

$$\tilde{\pi}_{t+k+\ell+1} - \tilde{\pi}_{t-1} = \eta_{q,\tau} \left(\tilde{\tau}_{t+k+\ell+1} - \tilde{\tau}_{t-1}\right)$$

that

$$\begin{aligned}\tilde{n}_{t+h} - \tilde{n}_{t-1} =& \chi \eta_{q,\tau} \frac{\delta + r}{1+r} \delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \mathbb{E}_{t+k}\left[\sum_{\ell=0}^{\infty} \left(\frac{1-\delta}{1+r}\right)^{\ell} (\tilde{\tau}_{t+k+\ell+1} - \tilde{\tau}_{t-1})\right] \\ &+ \chi \tilde{\pi}_{t-1}\left[1 - (1-\delta)^h\right] + \tilde{n}_t (1-\delta)^h - \tilde{n}_{t-1}.\end{aligned}$$

Since $\mathbb{E}_{t+k}\left[\tilde{\tau}_{t+k+\ell+1}\right] = \tilde{\tau}_{t+k}$, this expression becomes

$$\begin{aligned}\tilde{n}_{t+h} - \tilde{n}_{t-1} =& \chi \eta_{q,\tau} \delta \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \left(\tilde{\tau}_{t+k} - \tilde{\tau}_{t-1}\right) \\ &+ \chi \tilde{\pi}_{t-1}\left[1 - (1-\delta)^h\right] + \tilde{n}_t (1-\delta)^h - \tilde{n}_{t-1}.\end{aligned}$$

Now

$$
\begin{aligned}
\tilde{X}_{t+h}-\tilde{X}_{t-1} =& \tilde{q}_{t+h}-\tilde{q}_{t-1}+\tilde{p}^{x}_{t+h}-\tilde{p}^{x}_{t-1}+\tilde{n}_{t+h}-\tilde{n}_{t-1}\\
=& \tilde{q}_{t+h}-\tilde{q}_{t-1}+\tilde{p}^{x}_{t+h}-\tilde{p}^{x}_{t-1}+\chi\eta_{q,\tau}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\left(\tilde{\tau}_{t+k}-\tilde{\tau}_{t-1}\right)\\
&+\chi\tilde{\pi}_{t-1}\left[1-(1-\delta)^{h}\right]+\tilde{n}_{t}(1-\delta)^{h}-\tilde{n}_{t-1}
\end{aligned}
$$

and regressing this on $(\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1})$ gives

$$
\begin{aligned}
&\frac{\mathbb{C}ov\left(\tilde{X}_{t+h}-\tilde{X}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}{\mathbb{V}\left(\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)} &\text{(C.28)}\\
=&\frac{\mathbb{C}ov\left(\tilde{q}_{t+h}-\tilde{q}_{t-1}+\tilde{p}^{x}_{t+h}-\tilde{p}^{x}_{t-1}+\chi\eta_{q,\tau}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\left(\tilde{\tau}_{t+k}-\tilde{\tau}_{t-1}\right),\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}{\mathbb{V}\left(\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}\\
=&\frac{\mathbb{C}ov\left(\tilde{q}_{t+h}-\tilde{q}_{t-1}+\tilde{p}^{x}_{t+h}-\tilde{p}^{x}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}{\mathbb{V}\left(\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}+\frac{\mathbb{C}ov\left(\chi\eta_{q,\tau}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\left(\tilde{\tau}_{t+k}-\tilde{\tau}_{t-1}\right),\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}{\mathbb{V}\left(\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}\\
=&\varepsilon^{0}+\chi\eta_{q,\tau}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\frac{\mathbb{C}ov\left(\tilde{\tau}_{t+k}-\tilde{\tau}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}{\mathbb{V}\left(\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}\\
=&\varepsilon^{0}+\chi\eta_{q,\tau}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\frac{k+1}{h+1} &\text{(C.29)}
\end{aligned}
$$

where the last equality uses equation (C.27) above.

Next note that

$$
\begin{aligned}
\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\frac{k+1}{h+1} = & (1-\delta)^{h-1}\frac{1}{h+1}+(1-\delta)^{h-2}\frac{2}{h+1}+...+(1-\delta)\frac{h-1}{h+1}+\frac{h}{h+1} \\
= & \frac{1}{h+1}[1] \\
& +\frac{1}{h+1}[1+(1-\delta)] \\
& +... \\
& +\frac{1}{h+1}\left[1+(1-\delta)+...+(1-\delta)^{h-2}\right] \\
& +\frac{1}{h+1}\left[1+(1-\delta)+...+(1-\delta)^{h-2}+(1-\delta)^{h-1}\right] \\
= & \frac{1}{h+1}\sum_{k=0}^{h-1}\sum_{j=0}^{k}(1-\delta)^{j} \\
= & \frac{1}{h+1}\sum_{k=0}^{h-1}\frac{1-(1-\delta)^{k+1}}{\delta}.
\end{aligned}
$$

Plugging this expression into equation (C.29) gives

$$
\begin{aligned}
\frac{\mathbb{C}ov\left(\tilde{X}_{t+h}-\tilde{X}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)}{\mathbb{V}\left(\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1},\tilde{\tau}_{t+h}-\tilde{\tau}_{t-1}\right)} = & \varepsilon^{0}+\chi\eta_{q,\tau}\delta\frac{1}{h+1}\sum_{k=0}^{h-1}\frac{1-(1-\delta)^{k+1}}{\delta} \\
= & \varepsilon^{0}+\chi\eta_{q,\tau}\frac{1}{h+1}\sum_{k=0}^{h-1}\left[1-(1-\delta)^{k+1}\right] \\
= & \varepsilon^{0}+\chi\eta_{q,\tau}\frac{1}{h+1}\sum_{k=0}^{h}\left[1-(1-\delta)^{k}\right] \\
= & \frac{1}{h+1}\sum_{k=0}^{h}\varepsilon^{k}
\end{aligned}
$$

where we used that $\varepsilon^{h}=\varepsilon^{0}+\chi\eta_{q,\tau}\left(1-(1-\delta)^{h}\right)$, see equation (17) of Example 1.

□

C.6 Non-tariff trade barrier elasticities

As is conventional, we model non-tariff trade barriers κ_t as cost shifters in an iceberg form, which are specific to serving a particular destination (see Appendix C.1).

Short-run elasticity to non-tariff trade barriers The short-run non-tariff trade barrier elasticity is

$$\varepsilon_{\kappa}^{0} := \frac{d\ln X_{t_0}}{d\ln \kappa_{t_0}} = \frac{d\ln q_{t_0}}{d\ln \kappa_{t_0}} + \frac{d\ln p_{t_0}^{x}}{d\ln \kappa_{t_0}} = (1+\eta_{q,p})\,\eta_{p,c}, \tag{C.30}$$

where $\eta_{p,c} := \frac{\partial \ln p}{\partial \ln c}$. In the CES demand case $\eta_{p,c} = 1$ and $\eta_{q,p} = -\sigma$, so that $\varepsilon_{\kappa}^{0} = 1-\sigma$.

Long-run elasticity to non-tariff trade barriers The long-run non-tariff trade barrier elasticity is

$$\begin{aligned}
\varepsilon_{\kappa} := \frac{d\ln X}{d\ln \kappa} &= \frac{d\ln q}{d\ln \kappa} + \frac{d\ln p^{x}}{d\ln \kappa} + \frac{d\ln n}{d\ln \kappa} \\
&= \varepsilon_{\kappa}^{0} + \frac{d\ln n}{d\ln v}\frac{d\ln v}{d\ln \kappa} \\
&= \varepsilon_{\kappa}^{0} + \chi\frac{d\ln \pi}{d\ln \kappa} \\
&= \varepsilon_{\kappa}^{0} + \chi\eta_{\pi,c},
\end{aligned} \tag{C.31}$$

where $\eta_{\pi,c} := \frac{\partial \ln \pi}{\partial \ln c}$. In the CES case $\varepsilon_{\kappa}^{0} = 1-\sigma$ and $\eta_{\pi,c} = 1-\sigma$, so $\varepsilon_{\kappa} = -(\sigma-1)(1+\chi)$.

The horizon-h elasticity to non-tariff trade barriers We proceed analogously to the tariff shock discussed in Section V.A. Consider an impulse response to a non-tariff trade barrier shock at time t_0, denoted by $\left\{\frac{d\ln \kappa_{t_0+\ell}}{d\ln \kappa_{t_0}}\right\}_{\ell=1}^{\infty}$. The horizon-$h$ impulse response function of trade is

$$\frac{d\ln X_{t_0+h}}{d\ln \kappa_{t_0}} = \varepsilon_{\kappa}^{0}\frac{d\ln \kappa_{t_0+h}}{d\ln \kappa_{t_0}} + \frac{d\ln n_{t_0+h}}{d\ln \kappa_{t_0}}. \tag{C.32}$$

The horizon-h non-tariff trade barrier elasticity is then defined as

$$\varepsilon_{\kappa}^{h} := \frac{\frac{d\ln X_{t_0+h}}{d\ln \kappa_{t_0}}}{\frac{d\ln \kappa_{t_0+h}}{d\ln \kappa_{t_0}}} = \varepsilon_{\kappa}^{0} + \frac{\frac{d\ln n_{t_0+h}}{d\ln \kappa_{t_0}}}{\frac{d\ln \kappa_{t_0+h}}{d\ln \kappa_{t_0}}}. \tag{C.33}$$

Analogous to Proposition 1, it is straightforward to show that to a first order approximation around the steady state, the impulse response function of $\ln n_t$ at horizon h is

$$\frac{d\ln n_{t_0+h}}{d\ln \tau_{t_0}} = \chi\eta_{\pi,c}\frac{r+\delta}{1+r}\delta\sum_{k=0}^{h-1}(1-\delta)^{h-1-k}\,\mathbb{E}_{t_0+k}\left[\sum_{\ell=0}^{\infty}\left(\frac{1-\delta}{1+r}\right)^{\ell}\frac{d\ln \kappa_{t_0+k+\ell+1}}{d\ln \kappa_{t_0}}\right], \tag{C.34}$$

for $h = 0, 1, 2, \ldots$. Notice that in the CES case we have $\eta_{\pi,c} = 1-\sigma$.

Discussion While non-tariff trade barrier elasticities generally differ from tariff elasticities, the two are closely related in commonly used models, such as most static trade models and the class of dynamic models we consider. The mapping between the trade elasticity to tariffs and to non-tariff trade barriers in static models is well understood (see Section V.A for a discussion). Table C1 provides a summary for the dynamic models we consider, both for the general case and under CES

Table C1: Tariff versus non-tariff trade barrier elasticities

	Tariff elasticity	Non-tariff trade barrier elasticity
Panel A: General case		
Short-run	$\varepsilon^0 = (1+\eta_{q,p})\,\eta_{p,\tau} + \eta_{q,\tau}$	$\varepsilon^0_\kappa = (1+\eta_{q,p})\,\eta_{p,c}$
Long-run	$\varepsilon = \varepsilon^0 + \chi\eta_{\pi,\tau}$	$\varepsilon_\kappa = \varepsilon^0_\kappa + \chi\eta_{\pi,c}$
Horizon-h	eqns (14), (15), (16)	eqns (C.32), (C.33), (C.34)
Panel B: CES case		
Short-run	$\varepsilon^0 = -\sigma$	$\varepsilon^0_\kappa = -(\sigma-1)$
Long-run	$\varepsilon = -\sigma(1+\chi)$	$\varepsilon_\kappa = -(\sigma-1)(1+\chi)$
Horizon-h	eqns (14), (15), (16) with $\eta_{\pi,\tau} = -\sigma$	eqns (C.32), (C.33), (C.34) with $\eta_{\pi,c} = -(\sigma-1)$

demand. As above, these elasticities are of trade exclusive of tariffs, consistent with our empirical estimation.

The differences between these two sets of elasticities arise from the fact that non-tariff trade barriers are typically modeled as affecting the cost of delivering the goods to the importing consumer, while tariffs represent a wedge between the exporter price and the price faced by the importer. Importantly, tariffs leave the exporter's cost of serving the foreign market unchanged. This distinction matters both in the short run and in the long run.

For concreteness, we describe the CES case in detail. Beginning with the short run, tariff shocks have no impact on export prices $\eta_{p,\tau} = 0$. Trade flows are only affected by the direct effect of the tariff on import quantities, so that $\varepsilon^0 = \eta_{q,\tau} = -\sigma$. In contrast, a change in non-tariff trade barriers affects the cost of serving the foreign market and hence the exporter price: $\eta_{p,c} = 1$. The short-run trade response is then $\varepsilon^0_\kappa = 1 + \eta_{q,p} = 1 - \sigma$. Note that the price change for the importer is identical in both cases. In addition to the short run, these calculations also apply to the static trade models.

In the long run, elasticities for tariffs and iceberg trade costs differ also because the elasticity of profits with respect to tariffs differs from the elasticity of profits with respect to iceberg trade costs. In the CES case where profits are proportional to sales, higher tariffs reduce the quantity while leaving the exporter price unchanged. As a result, the elasticity of flow profits with respect to tariffs is $\eta_{\pi,\tau} = -\sigma$. Higher non-tariff trade costs have the same effect on the quantity, but also lead exporters to charge higher prices. As a result, $\eta_{\pi,c} = -\sigma + 1$. The responsiveness of the mass n to changes in the value v as captured by elasticity $\frac{d\ln n}{d\ln v} = \chi$ is independent of the shock.

We next turn to the horizon-h specific elasticities. If tariffs and non-tariff trade costs have the same impulse response function after an initial unitary impulse, that is, $\left\{\frac{d\ln\kappa_{t_0+\ell}}{d\ln\kappa_{t_0}}\right\}_{\ell=1}^{\infty} = \left\{\frac{d\ln\tau_{t_0+\ell}}{d\ln\tau_{t_0}}\right\}_{\ell=1}^{\infty}$, the shape of the impulse response function of trade is identical. To see this, note that the only difference between equations (16) and (C.34) is that the former is scaled by $\eta_{\pi,\tau}$ while the latter is scaled by $\eta_{\pi,c}$.

Most importantly, our estimates provide sufficient information to discipline both σ and χ (see also Section V.A), and hence our model can be used to make predictions about non-tariff elasticities as well. Specifically, for a given σ and a given χ, the model can be used to construct predictions about the short-run non-tariff trade barrier elasticity based on equation (C.30), the long-run non-tariff trade barrier elasticity based on equation (C.31), and the entire time path (equations C.32-C.34).

Appendix D General Equilibrium Model

D.1 Model setup

We consider a multi-country, multi-sector dynamic Krugman economy with N countries indexed by i and j and P sectors indexed by p.

D.1.1 Households

Intertemporal problem Let $C_{j,t}$ denote consumption in country j, β the discount factor, and γ the coefficient of relative risk aversion. Consumers in country j maximize

$$\max_{\{C_{j,t}\}} \sum_{t=0}^{\infty} \beta^t \frac{C_{j,t}^{1-\gamma}}{1-\gamma}$$

subject to the budget constraint

$$P_{j,t}C_{j,t} + \frac{B_{j,t}}{1+r_{j,t}^n} = w_{j,t}L_j + \Pi_{j,t} + R_{j,t} + B_{j,t-1}.$$

In this budget constraint, $P_{j,t}$, $B_{j,t}$, $r_{j,t}^n$, $w_{j,t}$, L_j, $\Pi_{j,t}$, and $R_{j,t}$ denote, respectively, the price index, a risk-free bond, the nominal interest rate, the nominal wage, the labor endowment, profits, and a rebate from the government in country j.

Taking prices as given, optimal household behavior requires that

$$C_{j,t}^{-\gamma} = (1+r_{j,t})\,\beta C_{j,t+1}^{-\gamma},$$

where $r_{j,t}$ is the real interest rate, defined as

$$1 + r_{j,t} := \left(1 + r_{j,t}^n\right) \frac{P_{j,t}}{P_{j,t+1}}.$$

Consumption over sectors The consumption aggregate is Cobb-Douglas over sectors, so that

$$C_{j,t} = \prod_p q_{j,p,t}^{\alpha_{j,p}},$$

where $q_{j,p,t}$ denotes the quantity of product p that country j consumes, and $\alpha_{j,p} > 0$ are parameters such that $\sum_p \alpha_{j,p} = 1$ for all j. Taking prices as given, households minimize costs

$$\min_{\{q_{j,p,t}\}} \sum_p P_{j,p,t} q_{j,p,t},$$

where $P_{j,p,t}$ is the price index of sector p in country j. Optimal behavior requires that

$$P_{j,p,t}q_{j,p,t} = \alpha_{j,p}C_{j,t}P_{j,t},$$

where the aggregate price index $P_{j,t}$ satisfies

$$P_{j,t} = \prod_p \left(\frac{P_{j,p,t}}{\alpha_{j,p}} \right)^{\alpha_{j,p}} .$$

Note that since nominal objects are not determined in this model, we often express the aggregate price index of country j relative to the US price index below. We denote the price index for the US as $P_{1,t} = P_{US,t}$.

D.1.2 Sectors

A sectoral aggregate combines varieties from potentially all countries i serving market j in sector p. In each sector p, there is a mass of firms $n_{j,i,p,t}$ that serves market j from country i at time t. With some abuse of notation, let $n_{i,j,p,t}$ denote both the measure of firms and the set of firms. Sectoral output is a constant elasticity of substitution (CES) aggregate of firm-level sales

$$q_{j,p,t} = \left(\sum_i \omega_{j,i,p,t}^{\frac{1}{\sigma}} \int_{\iota \in n_{j,i,p,t}} q_{j,i,p,t} \left(\iota\right)^{\frac{\sigma-1}{\sigma}} d\iota \right)^{\frac{\sigma}{\sigma-1}} , \tag{D.1}$$

where $q_{j,i,p,t}(\iota)$ is the quantity supplied by firm ι in country i to market j, and $\omega_{j,i,p,t}$ is a potentially time-varying taste shifter in j for products p coming from i. We assume that these shifters sum to unity across source countries in the steady state, that is $\forall j, p : \sum_i \omega_{j,i,p} = 1$. Parameter σ is the elasticity of substitution across varieties.

Denoting by $p^d_{j,i,p,t}$ the price paid in the destination, and taking prices as given, the aggregating firm in each sector solves

$$\max_{\{q_{j,i,p,t}(\iota)\}} P_{j,p,t} q_{j,p,t} - \sum_i \int_{\iota \in n_{j,i,p,t}} p^d_{j,i,p,t}(\iota)\, q_{j,i,p,t}(\iota)\, d\iota$$

subject to equation (D.1).

Optimal behavior yields the demand functions

$$q_{j,i,p,t}(\iota) = \omega_{j,i,p,t} q_{j,p,t} \left(\frac{p^d_{j,i,p,t}(\iota)}{P_{j,p,t}} \right)^{-\sigma} ,$$

where the sector-specific price index is

$$P_{j,p,t} = \left(\sum_i \omega_{j,i,p,t} \int_{\iota \in n_{j,i,p,t}} p^d_{j,i,p,t}(\iota)^{1-\sigma} d\iota \right)^{\frac{1}{1-\sigma}} .$$

D.1.3 Firms

Technology and trade costs Firms operate a linear technology

$$q_{j,i,p,t}(\iota) = \frac{z_{i,p,t}}{\kappa_{j,i,p,t}} l_{j,i,p,t}(\iota),$$

where $z_{i,p,t}$ is the technology common to all firms in sector p of country i, $\kappa_{j,i,p,t}$ are non-tariff trade costs of the iceberg type associated with serving country j, and $l_{j,i,p,t}(\iota)$ denotes the labor input. The unit cost of serving market j is therefore $\kappa_{j,i,p,t}\frac{w_{i,t}}{z_{i,p,t}}$.

In addition to the non-tariff trade barriers $\kappa_{j,i,p,t}$, which are associated with the loss of output during shipment, international trade is subject to tariffs. Tariffs represent a wedge between the price paid in the destination, $p^d_{j,i,p,t}(\iota)$, and the price received by producers, $p^x_{j,i,p,t}(\iota)$, that is, $p^d_{j,i,p,t}(\iota) = p^x_{j,i,p,t}(\iota)\,\tau_{j,i,p,t}$. As specified below, tariff revenue collected by an importer's government will be rebated to the domestic consumer.

Price setting, sales, and profits A firm ι's profits from serving market j are

$$\pi_{j,i,p,t}(\iota) = \max_{p_{j,i,p,t}(\iota)} \left(p^x_{j,i,p,t}(\iota) - \kappa_{j,i,p,t}\frac{w_{i,t}}{z_{i,p,t}}\right) q_{j,i,p,t}(\iota),$$

where the maximization is subject to the demand curve

$$q_{j,i,p,t}(\iota) = \omega_{j,i,p,t}\alpha_{j,p}\left(\frac{\tau_{j,i,p,t}p^x_{j,i,p,t}(\iota)}{P_{j,p,t}}\right)^{-\sigma}\frac{P_{j,t}}{P_{j,p,t}}C_{j,t}.$$

The producer's optimal price is

$$p^x_{j,i,p,t}(\iota) = p^x_{j,i,p,t} = \frac{\sigma}{\sigma-1}\frac{\kappa_{j,i,p,t}}{z_{i,p,t}}w_{i,t}.$$

Note that since this price is common across firms ι, quantities $q_{j,i,p,t}(\iota)$ are also common across firms and we henceforth drop the index ι.

Individual firms' sales exclusive of tariffs are

$$x_{j,i,p,t} := p^x_{j,i,p,t}q_{j,i,p,t} = (\tau_{j,i,p,t})^{-\sigma}\left(\frac{\sigma}{\sigma-1}\frac{\kappa_{j,i,p,t}}{P_{j,p,t}}\frac{w_{i,t}}{z_{i,p,t}}\right)^{1-\sigma}\omega_{j,i,p,t}\alpha_{j,p}P_{j,t}C_{j,t}.$$

Further, individual profits and payments to labor are, respectively,

$$\begin{aligned}\pi_{j,i,p,t} &= \frac{1}{\sigma}x_{j,i,p,t}, \\ w_{i,t}l_{j,i,p,t} &= \frac{\sigma-1}{\sigma}x_{j,i,p,t}.\end{aligned} \tag{D.2}$$

Dynamic part of firm problem Each period, there is a unit mass of potential entrants from country i and sector p into each destination market j (including the home market). In order to sell to a market starting next period, the entrant must pay a sunk cost $\xi_{j,i,p,t}(\iota)$ this period, which is measured in units of labor and drawn from distribution G. Once selling to a market, the firm exits exogenously with probability δ. The value (in nominal terms) of entering market j for a firm from i selling product p is

$$v^n_{j,i,p,t} = \frac{1}{1+r^n_{i,t}} \left[\pi_{j,i,p,t+1}(\iota) + (1-\delta)\, v^n_{j,i,p,t+1}\right].$$

Potential entrant ι enters whenever $w_{i,t}\xi_{j,i,p,t}(\iota) \leq v^n_{j,i,p,t}$. Thus, the mass of new entrants at t of firms from i serving j in p is $G(\frac{v^n_{j,i,p,t}}{w_{i,t}})$. The mass of firms from i serving destination j with product p then evolves according to

$$n_{j,i,p,t+1} = (1-\delta)\, n_{j,i,p,t} + G\left(\frac{v^n_{j,i,p,t}}{w_{i,t}}\right).$$

Letting $v_{j,i,p,t} := \frac{v^n_{j,i,p,t}}{P_{i,t}}$, the value of exporting can be written as

$$v_{j,i,p,t} = \frac{1}{1+r_{i,t}} \left[\frac{\pi_{j,i,p,t+1}}{P_{i,t+1}} + (1-\delta)\, v_{j,i,p,t+1}\right],$$

where we used the definition of the real interest rate in country i, and the law of motion becomes

$$n_{j,i,p,t+1} = (1-\delta)\, n_{j,i,p,t} + G\left(\frac{v_{j,i,p,t}}{\frac{w_{i,t}}{P_{i,t}}}\right).$$

The aggregate sunk costs of entry in country i period t in units of labor are

$$S_{i,t} = \sum_p \sum_j \int_{-\infty}^{\frac{v_{j,i,p,t}}{\frac{w_{i,t}}{P_{i,t}}}} \xi dG\left(\xi\right).$$

We will assume throughout that the distribution $G\left(\cdot\right)$ is inverse Pareto so that

$$G\left(\xi\right) = \left(b\xi\right)^{\chi} \text{ for } \xi \leq \frac{1}{b},$$

for some $b > 0$. Note that, as in Appendix C, this assumption implies that

$$\frac{g\left(\xi\right)\xi}{G\left(\xi\right)} = \chi,$$

where g is the density of G.

D.1.4 Government

The government in country j rebates its tariff revenues to households. The aggregate rebate is

$$R_{j,t} = \sum_p \sum_i \left(\tau_{j,i,p,t} - 1\right) n_{j,i,p,t} x_{j,i,p,t}.$$

D.1.5 Market clearing

Labor market Labor market clearing in country i requires

$$L_{i,t} = \sum_p \sum_j n_{j,i,p,t} l_{j,i,p,t} + S_{i,t}.$$

Bond market We consider the case of financial autarky so that for every country i and time t, $B_{i,t} = 0$.

D.2 Equilibrium

For a given calibration, and given sequences of exogenous processes $\{\omega_{j,i,p,t}\}$, $\{\kappa_{j,i,p,t}\}$, $\{\tau_{j,i,p,t}\}$, and $\{z_{i,p,t}\}$, the equilibrium consists of sequences of prices and quantities $\{C_{i,t}\}$, $\left\{\frac{w_{i,t}}{P_{i,t}}\right\}$, $\left\{\frac{P_{i,t}}{P_{US,t}}\right\}$, $\{S_{i,t}\}$, $\left\{\frac{P_{i,p,t}}{P_{i,t}}\right\}$, $\left\{\frac{x_{j,i,p,t}}{P_{i,t}}\right\}$, $\{v_{j,i,p,t}\}$, $\{n_{j,i,p,t}\}$ for $i = 1, ...N$, $j = 1, ..., N$, $p = 1, ..., P$, and $t = 0, 1, ...$, such that the following equations hold:

Trade balance: for all i and t

$$\sum_p \sum_j \frac{\frac{P_{j,t}}{P_{US,t}}}{\frac{P_{i,t}}{P_{US,t}}} n_{i,j,p,t} \frac{x_{i,j,p,t}}{P_{j,t}} = \sum_p \sum_j n_{j,i,p,t} \frac{x_{j,i,p,t}}{P_{i,t}}.$$

Aggregate price index: for all i and t

$$1 = \prod_p \left(\frac{1}{\alpha_{i,p}} \frac{P_{i,p,t}}{P_{i,t}}\right)^{\alpha_{i,p}}.$$

Sector-specific price index: for all j, p, and t

$$\frac{P_{j,p,t}}{P_{j,t}} = \left(\sum_i \omega_{j,i,p,t} n_{j,i,p,t} \left(\frac{\sigma}{\sigma - 1} \frac{\tau_{j,i,p,t} \kappa_{j,i,p,t}}{z_{i,p,t}} \frac{w_{i,t}}{P_{i,t}} \frac{\frac{P_{i,t}}{P_{US,t}}}{\frac{P_{j,t}}{P_{US,t}}}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}.$$

Bilateral product-specific trade flows per firm: for all j, i, p, and t

$$\frac{x_{j,i,p,t}}{P_{i,t}} = (\tau_{j,i,p,t})^{-\sigma} \left(\frac{\sigma}{\sigma-1} \frac{\kappa_{j,i,p,t}}{z_{i,p,t}} \frac{\frac{w_{i,t}}{P_{i,t}}}{\frac{P_{j,p,t}}{P_{j,t}}} \right)^{1-\sigma} \omega_{j,i,p,t} \alpha_{j,p} \left(\frac{\frac{P_{i,t}}{P_{US,t}}}{\frac{P_{j,t}}{P_{US,t}}} \right)^{-\sigma} C_{j,t}. \tag{D.3}$$

Value of exporting: for all j, i, p, and t

$$v_{j,i,p,t} = \beta \frac{C_{i,t+1}^{-\gamma}}{C_{i,t}^{-\gamma}} \left[\frac{1}{\sigma} \frac{x_{j,i,p,t+1}}{P_{i,t+1}} + (1-\delta)\, v_{j,i,p,t+1} \right]. \tag{D.4}$$

Law of motion of mass of firms: for all j, i, p, and t

$$n_{j,i,p,t+1} = (1-\delta)\, n_{j,i,p,t} + (b)^{\chi} \left(\frac{v_{j,i,p,t}}{\frac{w_{i,t}}{P_{i,t}}} \right)^{\chi}. \tag{D.5}$$

Labor market clearing: for all i, and t

$$L_{i,t} = \frac{\sigma-1}{\sigma} \frac{1}{\frac{w_{i,t}}{P_{i,t}}} \sum_p \sum_j n_{j,i,p,t} \frac{x_{j,i,p,t}}{P_{i,t}} + S_{i,t}.$$

Sunk costs: for all i, and t

$$S_{i,t} = \frac{\chi\,(b)^{\chi}}{\chi+1} \sum_p \sum_j \left(\frac{v_{j,i,p,t}}{\frac{w_{i,t}}{P_{i,t}}} \right)^{\chi+1}.$$

Initial values of $n_{j,i,p,0}$ are given for all i, j, p and $v_{j,i,p,t}$ satisfy a transversality condition for all i, j, p.

D.3 Mapping between partial and general equilibrium model

This model collapses to a version of our partial equilibrium model in Section V.A and Appendix C when aggregate general equilibrium objects are held constant. To see this, first note that product-specific bilateral trade in this model is

$$\frac{X_{j,i,p,t}}{P_{i,t}} = \frac{x_{j,i,p,t}}{P_{i,t}} n_{j,i,p,t}, \tag{D.6}$$

where $x_{j,i,p,t} = p^x_{j,i,p,t} q_{j,i,p,t}$. The trade flow $X_{j,i,p,t}$ is the model analogue of measured trade in the data. In this appendix we express $X_{j,i,p,t}$ and other nominal objects relative to the exporter's price index $P_{i,t}$, since nominal objects are not determined in this general equilibrium model. When mapping this general equilibrium model to the partial equilibrium model in Section V.A and Appendix C, $P_{i,t}$ must be held constant—as would be the case in a regression with source-country time fixed effects, which absorb this variation.

Next note that in this model $\frac{x_{j,i,p,t}}{P_{i,t}}$ is given by equation (D.3), showing that $\eta_{p,\tau} = 0$ and $\eta_{q,p} =$

$\eta_{q,\tau} = \eta_{\pi,\tau} = -\sigma$ (profits per firm are proportional to sales per firm, see equation D.2). Other than tariffs, all determinants of $\frac{x_{j,i,p,t}}{P_{i,t}}$ according to equation (D.3) above are held constant in the partial equilibrium model.

Equation (8) in the text follows from equation (D.4) and noting that in the partial equilibrium model the discount rate

$$\frac{1}{1+r_{i,t}} = \beta \frac{C_{i,t+1}^{-\gamma}}{C_{i,t}^{-\gamma}}$$

is held constant and that individual firms' profits are $\frac{\pi_{j,i,p,t}}{P_{i,t}} = \frac{1}{\sigma}\frac{x_{j,i,p,t}}{P_{i,t}}$, see equation (D.2).

Equation (9) follows from equation (D.5), if the real wage is held constant at $\frac{w_i}{P_i}$ and

$$G\left(v_{j,i,p,t}\right) = (b)^{\chi}\left(\frac{v_{j,i,p,t}}{\frac{w_i}{P_i}}\right)^{\chi}.$$

D.4 Estimating equation and partial versus total elasticity

While the trade elasticity can be defined as a partial or a total elasticity, we estimated a partial elasticity in this paper. Specifically, our baseline estimates hold exporter-product-time and importer-product-time variation fixed by including the appropriate fixed effects in the regression. Similar to Proposition 3, we next show what precisely this partial elasticity captures in the context of this specific model and which determinants of bilateral trade flows are absorbed by the fixed effects.

To do so, consider the linearized versions of equations (D.6), (D.3), (D.5), and (D.4) above. Using tildes to denote relative deviations from steady state, these are

$$\begin{aligned}
\widetilde{\frac{X_{j,i,p,t}}{P_{i,t}}} &= \tilde{n}_{j,i,p,t} + \widetilde{\frac{x_{j,i,p,t}}{P_{i,t}}}, \\
\widetilde{\frac{x_{j,i,p,t}}{P_{i,t}}} &= -\sigma\tilde{\tau}_{j,i,p,t} + \tilde{m}^{s,1}_{i,p,t} + \tilde{m}^{d}_{j,p,t} + \tilde{\epsilon}_{j,i,p,t}, \\
\tilde{v}_{j,i,p,t} &= \tilde{m}^{s,2}_{i,t} + \left(1-\beta\left(1-\delta\right)\right)\widetilde{\frac{x_{j,i,p,t+1}}{P_{i,t+1}}} + \beta\left(1-\delta\right)\tilde{v}_{j,i,p,t+1}, \\
\tilde{n}_{j,i,p,t+1} &= \left(1-\delta\right)\tilde{n}_{j,i,p,t} + \chi\delta\tilde{v}_{j,i,p,t} - \tilde{m}^{s,3}_{i,t},
\end{aligned}$$

where we defined

$$\begin{aligned}
\tilde{m}^{s,1}_{i,p,t} &:= (\sigma-1)\,\tilde{z}_{i,p,t} - (\sigma-1)\,\widetilde{\frac{w_{i,t}}{P_{i,t}}} - \sigma\widetilde{\frac{P_{i,t}}{P_{US,t}}},\\
\tilde{m}^{s,2}_{i,t} &:= -\gamma\tilde{C}_{i,t+1} + \gamma\tilde{C}_{i,t},\\
\tilde{m}^{s,3}_{i,t} &:= \chi\delta\widetilde{\frac{w_{i,t}}{P_{i,t}}},\\
\tilde{m}^{d}_{j,p,t} &:= (\sigma-1)\,\widetilde{\frac{P_{j,p,t}}{P_{j,t}}} + \sigma\widetilde{\frac{P_{j,t}}{P_{US,t}}} + \tilde{C}_{j,t},\\
\tilde{\epsilon}_{j,i,p,t} &:= -\,(\sigma-1)\,\tilde{\kappa}_{j,i,p,t} + \tilde{\omega}_{j,i,p,t}.
\end{aligned}$$

To understand the motivation for this notation, note that $\tilde{m}^{s,1}_{i,p,t}$, $\tilde{m}^{s,2}_{i,t}$, $\tilde{m}^{s,3}_{i,t}$, and $\tilde{m}^{d}_{j,p,t}$ will ultimately be absorbed by the exporter-product-time and importer-product time fixed effects. The specific meaning of these terms is as follows. The term $\tilde{m}^{s,1}_{i,p,t}$ captures supply conditions in the source country, such as productivity $\tilde{z}_{i,p,t}$ and the real wage $\widetilde{\frac{w_{i,t}}{P_{i,t}}}$. The term $\tilde{m}^{s,2}_{i,t}$ captures time variation in the discount rate, which affects the value of exporting. Next, the term $\tilde{m}^{s,3}_{i,t}$ also reflects variation in the real wage $\widetilde{\frac{w_{i,t}}{P_{i,t}}}$. It is relevant here, because the sunk costs of exporting are denominated in units of labor and, all else equal, a higher real wage raises the costs of entering a new market. Lastly, the term $\tilde{m}^{d}_{j,p,t}$ captures demand shifters in the destination. Also note that the real exchange rate between country i and j is broken up into two terms. The exporter's price index relative to the US $\widetilde{\frac{P_{i,t}}{P_{US,t}}}$ enters $\tilde{m}^{s,1}_{i,p,t}$, and the price index of the importer relative to the US $\widetilde{\frac{P_{j,t}}{P_{US,t}}}$ is included in $\tilde{m}^{d}_{j,p,t}$. The time-varying bilateral and product-specific components of $\tilde{\epsilon}_{j,i,p,t}$, which include non-tariff trade barriers and demand shocks, will enter the error term.

It is now straightforward to repeat the derivations from Proposition 3 in the context of this specific model. Doing so yields the estimating equation for trade flows

$$\begin{aligned}
\widetilde{\frac{X_{j,i,p,t+h}}{P_{i,t+h}}} - \widetilde{\frac{X_{j,i,p,t-1}}{P_{i,t-1}}} =& -\sigma\left(\tilde{\tau}_{j,i,p,t+h} - \tilde{\tau}_{j,i,p,t-1}\right)\\
& -\sigma\left(1-\beta\left(1-\delta\right)\right)\delta\chi\sum_{k=0}^{h-1}\left(1-\delta\right)^{h-1-k}\sum_{\ell=0}^{\infty}\left(\beta\left(1-\delta\right)\right)^{\ell}\left(\tilde{\tau}_{j,i,p,t+k+\ell+1} - \tilde{\tau}_{j,i,p,t-1}\right)\\
& +\delta^{s,X,h}_{i,p,t} + \delta^{d,X,h}_{j,p,t} + u^{X}_{j,i,p,t},
\end{aligned} \tag{D.7}$$

where the fixed effects are

$$\delta^{s,X,h}_{i,p,t} := \left(\tilde{m}^{s,1}_{i,p,t+h} - \tilde{m}^{s,1}_{i,p,t-1}\right) + (1-\beta(1-\delta))\,\delta\chi \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \sum_{\ell=0}^{\infty} (\beta(1-\delta))^{\ell}\, \tilde{m}^{s,1}_{i,p,t+k+\ell+1}$$
$$+ \delta\chi \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \sum_{\ell=0}^{\infty} (\beta(1-\delta))^{\ell}\, \tilde{m}^{s,2}_{i,t+k+\ell} - \sum_{k=0}^{h-1} (1-\delta)^{h-1-k}\, \tilde{m}^{s,3}_{i,t+k},$$
$$\delta^{d,X,h}_{j,p,t} := \left(\tilde{m}^{d}_{j,p,t+h} - \tilde{m}^{d}_{j,p,t-1}\right) + (1-\beta(1-\delta))\,\delta\chi \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \sum_{\ell=0}^{\infty} (\beta(1-\delta))^{\ell}\, \tilde{m}^{d}_{j,p,t+k+\ell+1},$$

and the error term includes initial conditions, as well as leads and lags of $\tilde{\epsilon}_{j,i,p,t}$. Specifically,

$$u^{X}_{j,i,p,t} := -\sigma\chi\left(1-(1-\delta)^{h}\right)\tilde{\tau}_{j,i,p,t-1} + (1-\delta)^{h}\,\tilde{n}_{j,i,p,t} - \tilde{n}_{j,i,p,t-1}$$
$$+ \left(\tilde{\epsilon}_{j,i,p,t+h} - \tilde{\epsilon}_{j,i,p,t-1}\right) + (1-\beta(1-\delta))\,\delta\chi \sum_{k=0}^{h-1} (1-\delta)^{h-1-k} \sum_{\ell=0}^{\infty} (\beta(1-\delta))^{\ell}\, \tilde{\epsilon}_{j,i,p,t+k+\ell+1}.$$

The partial elasticity implied by equation (D.7) thus holds $\delta^{s,X,h}_{i,p,t}$ and $\delta^{d,X,h}_{j,p,t}$ fixed when subjecting trade flows to a trade shock at t_0. This amounts to holding supply conditions in the source country and demand conditions in the destination country fixed. When mapping to the partial equilibrium framework in Section V.A, a sufficient condition for this is that the terms $\tilde{z}_{i,p,t} = \widetilde{\frac{w_{i,t}}{P_{i,t}}} = \widetilde{\frac{P_{i,t}}{P_{US,t}}} = \tilde{C}_{i,t} = 0$ for all $t \geq t_0$ in the source country i and sector p, and that $\widetilde{\frac{P_{j,p,t}}{P_{j,t}}} = \widetilde{\frac{P_{j,t}}{P_{US,t}}} = \tilde{C}_{j,t} = 0$ for all $t \geq t_0$ in the destination country j and sector p.

The importer-product-time effects $\delta^{d,X,h}_{j,p,t}$ and exporter-product-time effects $\delta^{s,X,h}_{i,p,t}$ absorb both the exogenous (shocks) and endogenous (general-equilibrium) shifts in demand and supply. In particular, $\delta^{d,X,h}_{j,p,t}$ contains log-differences of the past, present, and expected future foreign demand shifters $\tilde{m}^{d}_{j,p,t}$, which are made up of the aggregate expenditures and the price levels in the destination j. Thus, the $\delta^{d,X,h}_{j,p,t}$s absorb any effect of a change in tariffs on the demand faced by exporter i through general-equilibrium effects in the importing country, such as the importer's prices and wages. Importer and third-country productivity shocks are absorbed by the importer-product-time effects, as they are part of the demand shifter $\tilde{m}^{d}_{j,p,t}$ (recall that $\tilde{m}^{d}_{j,p,t}$ includes the price level in destination j, and thus is a function of the productivities of all countries serving j, including j itself). Taste shocks that vary by destination (but not by destination-source) at the product level are also absorbed by the importer-time effects.

The exporter-product-time effects $\delta^{s,X,h}_{i,p,t}$ absorb the exogenous shocks and general-equilibrium effects in the exporting country, as it is made up of log-differences in current and expected future unit costs of production and entry. Thus, $\delta^{s,X,h}_{i,p,t}$s control for any general-equilibrium effect of a tariff change on wages of the exporter. In addition, exporter-product-specific productivity shocks are absorbed by the $\delta^{s,X,h}_{i,p,t}$s, as they manifest themselves in shifts in $\tilde{m}^{s,1}_{i,p,t}$, and in wages and prices indirectly. Trade cost shocks that vary either by destination-product-time or source-product-time are similarly absorbed by $\delta^{s,X,h}_{i,p,t}$ and $\delta^{d,X,h}_{j,p,t}$. On the other hand, taste and trade cost shocks that vary at the destination-source-product-time level $\omega_{i,j,p,t}$ and $\kappa_{i,j,p,t}$ are in the error term and if correlated to tariff changes, present a threat to identification.

While the intuition is generally similar to the role of multilateral resistance terms in static trade models (Anderson and van Wincoop, 2003), there are slight differences. For instance, the exporter-product-time fixed effect also absorbs variation in the discount rate, captured here by time variation in consumption of the source country, which affects the export entry decision of firms.

In contrast to the partial elasticity estimated in the data, the total trade response or total trade elasticity also takes general equilibrium effects of the tariff change into account. We compute it numerically below.

D.5 Calibration and model solution

The calibration of the model is parsimonious and uses readily available data. Data on real GDP comes from the Penn World Tables v.9.1 for 2006 and disciplines country size parameters (L_i). Specifically, we choose L_i such that relative steady state consumption C_i in the countries is equal to relative GDP in the data. Preference parameters in the final goods aggregator $\alpha_{i,p}$ are determined by sectoral expenditure share data for 2006 from KLEMS. In the model, import shares are determined by several parameters – tariffs $\tau_{i,j,p}$, productivity $z_{i,p}$, non-tariff trade barriers $\kappa_{i,j,p}$, and preference parameters $\omega_{i,j,p}$. We choose tariffs $\tau_{i,j,p}$ to be equal to the average import tariff set by i across all products belonging to sector p exported by j in 2006 in our data. The productivity parameters $z_{i,p}$ are chosen to match sectoral value added per worker from KLEMS in 2006. We cannot separately identify $\kappa_{i,j,p}$ and $\omega_{i,j,p}$. We therefore choose $\omega_{i,j,p} = \frac{1}{N}$ and then choose $\kappa_{i,j,p}$ to match observed 2006 import shares given the values of $\tau_{i,j,p}$, $z_{i,p}$, and $\omega_{i,j,p}$.

We parameterize the distribution of sunk entry costs in the model by assuming they are distributed inverse Pareto with an upper bound $b = 1$ and curvature parameter χ. In this dynamic Krugman model, the choice of σ and χ pins down the long run elasticity. Given a short run elasticity σ of 1.1, we choose $\chi = 0.82$ for the baseline calibration such that the long run elasticity is 2. Finally, our model also requires the calibration of several standard parameters summarized in Table D1.

Our quantitative exercises fall into two categories. For the first, we linearize the GE model and compute the partial and general equilibrium impulse responses to tariff changes under a variety of scenarios. For this exercise, we choose $N = 6$ and $P = 5$ (a six-country and five-sector model). These choices are largely determined by the scale of a model that can be solved using standard computational software. In this setting, the economies we use as calibration targets are the US, Europe, China, Canada, Japan and a rest-of-the world aggregate. The sectors we choose are services (largely non-traded), three manufacturing sectors (upstream, non-durable, and machinery), and one non-manufacturing traded sector including agriculture and other traded non-manufacturing goods. We use this calibration for the exercises underlying Figures 6 and B6.

In the second exercise, we compute the dynamic welfare gains from trade country-by-country. We use a standard shooting algorithm for this exercise. For simplicity, we consider one country at a time as well as a rest-of-the-world aggregate, so that $N = 2$. We also collapse the sectoral dimension to $P = 2$, with one traded and one non-traded sector. For this exercise, therefore, we compute 23 different versions of the model, and in each case $N = 2$ and $P = 2$.

The gains from trade are then computed as follows. We first compute the steady states under autarky (A) and the observed level of trade (T) and infer the change in non-tariff trade costs $\kappa^T_{j,i,p} - \kappa^A_{j,i,p}$ required to generate the difference in trade across steady states observed in the data. All other parameters remain unchanged in this exercise. We then consider a one-time unexpected permanent non-tariff trade cost change of the required magnitude, occurring at the beginning of period 0, and compute the transition path from autarky to the new steady state.

The remaining calculations are analogous to the Lucas welfare cost of business cycles calculation. In general, the value of consumption is

$$V_{j,0} = \sum_{t=0}^{\infty} \beta^t \frac{(C_{j,t})^{1-\gamma}}{1-\gamma}.$$

Consider the transition path from the autarky steady state to the new steady state with trade. Since the shock occurs at the beginning of $t = 0$, we can compute the value as

$$V^T_{j,0} = \sum_{t=0}^{\infty} \beta^t \frac{\left(C^T_{j,t}\right)^{1-\gamma}}{1-\gamma}.$$

Next, consider an equivalent value arising under the thought experiment where the household receives a consumption equivalent $C^{T,e}_j$ for all $t \geq 0$ going forward,

$$V^{T,e}_{j,0} = \sum_{t=0}^{\infty} \beta^t \frac{\left(C^{T,e}_j\right)^{1-\gamma}}{1-\gamma}.$$

Setting $V^T_{j,0} = V^{T,e}_{j,0}$ gives

$$C^{T,e}_j = \left((1-\beta)\sum_{t=0}^{\infty} \beta^t \left(C^T_{j,t}\right)^{1-\gamma}\right)^{\frac{1}{1-\gamma}}.$$

The dynamic welfare gains are then computed as

$$\mathrm{GFT}_j = \frac{C^{T,e}_j - C^A_j}{C^A_j},$$

where C^A_j is consumption in the autarky steady state. This exercise delivers Figure B8.

Table D1: Parameterization

Parameter(s)	Value /Target /Source	Notes
β	0.97	Discount factor
γ	2	Relative risk aversion
δ	0.25	Exit rate
b	1	Inverse Pareto upper bound
$\alpha_{i,p}$	KLEMS	Expenditure shares
$\tau_{j,i,p}$	TRAINS	Average bilateral tariffs
$z_{i,p}$	KLEMS	Sectoral value added per worker
$\omega_{j,i,p}$	$\frac{1}{N}$	Preference parameters
$\kappa_{j,i,p}$	WIOD import shares	Non-tariff trade costs
L_i	PWT	Chosen to match relative real GDP
Elasticity Parameters: Baseline calibration		
σ	1.1	Short-run trade elasticity
χ	0.82	Pareto curvature parameter
Elasticity Parameters: High elasticity calibration		
σ	3	Short-run trade elasticity
χ	1	Pareto curvature parameter

Notes: This table summarizes calibration of the dynamic Krugman model. All data used are for year 2006. Our quantitative exercises either have countries $N = 2$ and sectors $P = 2$ or countries $N = 6$ and sectors $P = 5$. When $N = 2$, $P = 2$ we (i) normalize value added per worker in the traded sector in the country of interest equal to 1; (ii) choose L_i in the country of interest such that real GDP in the country of interest is 1 in the steady state with trade. When $N = 6$, $P = 5$ we (i) normalize value added per worker in the machinery sector in the United States equal to 1; (ii) choose L_{US} such that real GDP in the US is equal to 1.

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