Supplement to "Heterogeneous effects of tariff and nontariff trade-policy barriers in quantitative general equilibrium"

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Appendix A: Generic theoretical background

In customary quantitative multicountry—so-called gravity—models of international trade aggregate bilateral trade depends on three major components: (endogenous plus exogenous) exporter-specific factors, exporter-importer-specific trade-cost factors, and (endogenous plus exogenous) importer-specific factors, which are structurally linked to the former two components (see Anderson and van Wincoop (2003), Arkolakis, Costinot, and Rodriguez-Clare (2012), Head and Mayer (2014), Egger and Nigai (2015)). This relationship can be extended to the sector level, where all of the aforementioned components vary additionally across sectors (see, e.g., Costinot, Donaldson, and Komunjer (2012), Caliendo and Parro (2015)). The second, bilateral-trade-cost component is typically assumed to be exogenous in structural empirical (and quantitative) models of bilateral trade.[1]

This paper parts with the notion of the exogeneity of tariffs and nontariff trade-policy measures in models with log-linear direct trade-cost effects and permits their link to ad valorem trade costs to be flexible. Doing so in a structural multicountry, multisector approach rests on four pillars: first, a decomposition of bilateral trade flows into the aforementioned three components; second, a further decomposition of the country-sector-specific factors into endogenous and exogenous fundamental components in or-

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[1] Clearly, we have seen interesting progress over the past years, documenting that general-equilibrium effects of trade-policy changes depend on model details such as the consideration of input–output linkages (Ossa, 2015, Caliendo and Parro, 2015), factor mobility (Redding, 2016, Allen and Donaldson, 2019), or dynamic factor adjustments (Anderson, Larch, and Yotov, 2017). However, these mechanisms all play out in general equilibrium, and hence, in variables which are inherently country(-sector-time) but not country-pair(-sector-time) indexed. The argument at heart of this paper is that an important source of further heterogeneity of general equilibrium effects lies in the partial heterogeneity of trade-cost responses to trade-policy changes, and this heterogeneity has fundamentally to do with the level of trade freeness applied in the outset. Hence, the issue addressed here adds to every one of the aforementioned sources of modified effects of trade costs in general equilibrium, all of which are concerned with the link between trade costs and factor prices rather than with the make-up (or the functional form) of trade costs per se.

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der to determine the joint drivers of endogenous tariff and nontariff trade-policy variables on the one hand, and of trade flows on the other hand; third, a flexible determination of the tariff and nontariff trade-policy variables as a function of the distilled country-sector-specific exogenous fundamentals as well as of natural (nonpolicy) trade costs to extract the random component of the trade-policy measures; and, finally, a flexible determination of total exporter-importer-sector-specific trade costs as a function of the randomized tariff and nontariff measures. The latter function then can be used in any quantitative model to evaluate effects of trade-policy changes in general equilibrium. The purpose of the present section is to outline a procedure to accomplish this task.

A.1 *A stylized trade model*

Consider a general equilibrium model of bilateral trade in $s = 1, \dots, S$ sectors among $i, j = 1, \dots, J$ exporting and importing countries. As the general structure of the model is consistent with a host of approaches proposed in earlier work (see Arkolakis, Costinot, and Rodriguez-Clare (2012)), the write-up can be relatively generic and parsimonious.

For the sake of simplicity, let us resort to a single-factor framework on the supply side, with L_i^s denoting (simple or equipped) labor used by sector s in country i.[2] Additionally, with notable relevance only for the counterfactual equilibrium analysis but not for estimation, assume L_i^s to be immobile across sectors s and countries j. Accordingly, the cost per unit of factor usage will be specific to both countries and sectors, W_i^s. Factor-market clearing implies that the value of sales (and production) in each country and sector, Y_i^s, is spent on the respective factors used:[3]

$$Y_i^s = W_i^s L_i^s. \tag{S.1}$$

Product-market clearing implies that aggregate expenditures in an economy, E_i, correspond to factor income plus aggregate transfers, B_i.[4] The latter we will assume to be financed by tariff revenues from all sectors, B_i^s. Accordingly, we obtain

$$E_i = \sum_{s=1}^{S} \left(Y_i^s + B_i^s \right). \tag{S.2}$$

It is customary to assume that a fixed share $\beta_i^s = (0, 1)$ with $\sum_{s=1}^{S} \beta_i^s = 1$ of all expenditures is devoted to sector s, so that we can define sector-level expenditures as $E_i^s = \beta_i^s E_i$.

[2]The notion of *equipped labor* is used in earlier work in order to emphasize that L_i^s may represent, for example, a Cobb–Douglas aggregate of several factors, one of them being labor. Accordingly, W_i^s would then measure the cost of the bundle of the factors involved. The fact that hourly wages and other factor costs vary across sectors within countries and within sectors across countries is consistent with some element of sector specificity of factors as assumed here. Since sector specificity rules out any reallocation of factors of production across sectors, equilibrium changes associated with changes in trade costs should be interpreted as short- or medium-run equilibrium effects.

[3]This customary specification excludes, for example, fixed market-entry costs, which are borne by the importing country.

[4]One could easily incorporate a notion of trade imbalances along the lines of Dekle, Eaton, and Kortum (2007). We will do so in the empirical part but suppress this argument here for the sake of simplicity.

Use X_{ij}^s and $t_{ij}^s \geq 0$ with $t_{ii}^s = 0$ to denote bilateral nominal exports (from i to j) or imports (of j from i) and the ad valorem tariff rate charged by j on imports from i, respectively. Then we can specify a generic gravity equation for X_{ij}^s and sector-level tariff revenues in j, B_j^s, as

$$X_{ij}^s = \pi_{ij}^s E_j^s, \qquad \pi_{ij}^s = \frac{A_i^s C_{ij}^s}{\sum_{k=1}^{J} A_k^s C_{kj}^s}, \qquad B_j^s = \sum_{s=1}^{S} \sum_{i=1}^{J} \frac{t_{ij}^s}{1+t_{ij}^s} X_{ij}^s, \tag{S.3}$$

where A_i^s subsumes any exporter-sector-specific determinants and C_{ij}^s subsumes all the country-pair-sector-specific trade-cost components including tariffs, $(1+t_{ij}^s)$, and non-tariff barriers, $(1+n_{ij}^s)$, each expressed in ad valorem terms. Obviously, this specification guarantees the accounting identity of bilateral consumption shares to hold, $\sum_{i=1}^{J} \pi_{ij}^s = 1$. In the remainder, we will broadly associate C_{ij}^s with trade costs, being aware that C_{ij}^s may include an (isomorphic) Armington-type consumer-preference parameter in country j toward s-type output from i.

As indicated above, the component A_i^s has a wide range of interpretations (see Arkolakis, Costinot, and Rodriguez-Clare (2012)). However, the key requirement on it here is that it is log-additive in endogenous (W_i^s) and exogenous determinants (F_i^s) of exporter potential:

$$A_i^s = F_i^s \left(W_i^s\right)^{\alpha_s}, \tag{S.4}$$

where F_i^s contains all exogenous exporter-sector-specific fundamental drivers of trade. These fundamentals can comprise supply-side factors such as factor endowments, productivity parameters, and measures of comparative advantage as well as demand-side factors such as Armington-type preference parameters.[5] Accordingly, the structural interpretation of the sector-specific elasticity α_s depends on the respective fundamentals, and hence, the specifics of the structural trade model assumed.

Armed with these definitions, we can rewrite the product-market-clearing condition as

$$\underbrace{W_i^s L_i^s}_{Y_i^s} = \sum_{j=1}^{J} \frac{1}{1+t_{ij}^s} \underbrace{\frac{F_i^s \left(W_i^s\right)^{\alpha_s} C_{ij}^s}{\sum_k F_k^s \left(W_k^s\right)^{\alpha_s} C_{kj}^s}}_{\pi_{ij}^s} \beta_j^s \underbrace{\sum_{s=1}^{S} \frac{L_j^s W_j^s}{1 - \sum_s \sum_k \frac{t_{kj}^s}{1+t_{kj}^s} \pi_{kj}^s \beta_j^s}}_{E_j^s}, \tag{S.5}$$

which determines W_i^s implicitly up to a scalar as a function of the other arguments.

[5] Adão, Costinot, and Donaldson (2017) establish a quantitative trade model supporting nonparametric effects of preferences and technology—both of which are ingredients of F_i^s—on A_i^s and trade flows. The interest here is on a nonparametric link between endogenous trade policy and overall trade costs on the one hand, and trade flows on the other hand, an issue which is not addressed in Adão, Costinot, and Donaldson (2017). Hence, the two approaches appear complementary to each other.

Let us refer to α_s, the exponent in (5), as the trade elasticity (i.e., the direct elasticity of trade flows with respect to prices, factor costs, and ad valorem trade costs). Then, after introducing the ad valorem trade-cost parameter D_{ij}^s and using the convention of denoting the log of any variable V by its lowercase counterpart v, we may specify

$$C_{ij}^s = \left(D_{ij}^s\right)^{\alpha_s} \quad \text{and} \quad c_{ij}^s = \alpha_s d_{ij}^s. \tag{S.6}$$

We will assume that log ad valorem trade costs, d_{ij}^s, are an arbitrary function of a policy vector of two endogenous elements $m_{ij}^s = (\tau_{ij}^s, \eta_{ij}^s)$ and a vector of (exogenous) remainder, natural other trade costs u_{ij}^s, $d_{ij}^s(m_{ij}^s, u_{ij}^s)$. Assuming log-additive separability between exogenous and endogenous determinants of trade costs and trade flows, we may specify log ad valorem trade costs d_{ij}^s as

$$d_{ij}^s = h\left(m_{ij}^s\right) + u_{ij}^s \gamma^s, \tag{S.7}$$

where $h(\cdot)$ is a flexible parametric or nonparametric function to allow for potential heterogeneity of the partial effect of trade costs (and trade flows) with respect to the trade-policy variables in m_{ij}^s.

A.2 *General-equilibrium effects of changes in specific trade-policy components in the trade-cost function*

With a specific trade-cost function in (S.7) at hand, the effect of any trade-policy intervention associated with a change from benchmark-state values (m_{ij}^s) $\forall i, j, s$ to counterfactual-state values $(m_{ij}^{s\prime})$ translates to a change of trade-cost values from (d_{ij}^s) to $(d_{ij}^{s\prime})$. Rewriting equation (S.5) for the counterfactual scenario reads

$$Y_i^{s\prime} L_i^s = \sum_{j=1}^{J} \frac{1}{1+t_{ij}^{s\prime}} \pi_{ij}^{s\prime} \beta_j^s \sum_{s=1}^{S} \frac{L_j^s W_j^{s\prime}}{1 - \sum_s \sum_k \frac{t_{kj}^{s\prime}}{1+t_{kj}^{s\prime}} \pi_{kj}^{s\prime} \beta_j^s}, \tag{S.8}$$

Following Dekle, Eaton, and Kortum (2007) in spirit, we use the following dot notation for any generic variable $\dot{V} = V'/V \leftrightarrow V' = \dot{V} V$. Note that $\dot{Y}_i^s = \dot{W}_i^s$ as markets clear and labor endowments are unchanged. Therefore,

$$\dot{Y}_i^s Y_i^s = \sum_{j=1}^{J} \frac{1}{1+t_{ij}^{s\prime}} \dot{\pi}_{ij}^s \pi_{ij}^s \beta_j^s \sum_{s=1}^{S} \frac{\dot{Y}_j^s Y_j^s}{1 - \sum_s \sum_k \frac{t_{kj}^{s\prime}}{1+t_{kj}^{s\prime}} \dot{\pi}_{kj}^s \pi_{kj}^s \beta_j^s}. \tag{S.9}$$

Noting that

$$\dot{\pi}_{ij}^s = \frac{\left(\dot{Y}_i^s \dot{D}_{ij}^s\right)^{\alpha_s}}{\sum_k \left(\dot{Y}_k^s \dot{D}_{kj}^s\right)^{\alpha_s} \pi_{kj}^s \sum_l F_l^s \left(W_l^s\right)^{\alpha_s} C_{lj}^s} \sum_k F_k^s \left(W_k^s\right)^{\alpha_s} C_{kj}^s$$

$$= \frac{\left(\dot{Y}_i^s \dot{D}_{ij}^s\right)^{\alpha_s}}{\sum_k \left(\dot{Y}_k^s \dot{D}_{kj}^s\right)^{\alpha_s} \pi_{kj}^s} \tag{S.10}$$

leads to the following counterfactual general-equilibrium changes:

$$\dot{Y}_i^s = \frac{1}{Y_i^s} \sum_{j=1}^{J} \frac{1}{1+t_{ij}^{s\prime}} \pi_{ij}^s \underbrace{\frac{\left(\dot{Y}_i^s \dot{D}_{ij}^s\right)^{\alpha_s}}{\sum_k \pi_{kj}^s \left(\dot{Y}_k^s \dot{D}_{kj}^s\right)^{\alpha_s}}}_{\dot{\pi}_{ij}^s} \beta_j^s \underbrace{\frac{\sum_s \dot{Y}_j^s Y_j^s}{1 - \sum_s \sum_k \frac{t_{kj}^{s\prime}}{1+t_{kj}^{s\prime}} \pi_{kj}^s \beta_j^s \dot{\pi}_{kj}^s}}_{E_j^{s\prime}}. \tag{S.11}$$

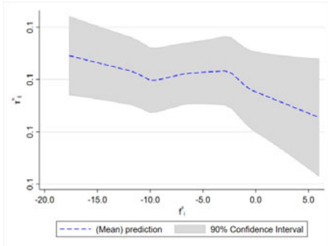
For the counterfactual exercise conducted in Section A.2, we need to define two parameters for every tuple $\{ijs\}$ given the tariff rate in the outset, t_{ij}^s: the counterfactual level of tariffs, $t_{ij}^{s\prime}$, and the change in overall ad valorem trade costs associated with a change of the tariff rate from t_{ij}^s to $t_{ij}^{s\prime}$, $\dot{D}_{ij}^s$. As we consider a (customary) constant-gradient and a flexible-gradient version of trade costs, there is a unique set of benchmark and counterfactual tariff-rate levels t_{ij}^s and $t_{ij}^{s\prime}$, respectively, but there are two alternative sets of trade-cost responses, $\dot{D}_{ij}^s$, one corresponding to the heterogeneous gradient estimated in the previous section, $\dot{D}_{ij}^{s,\text{flex.gradient}}$, and one corresponding to the customary approach of an ad valorem gradient, $\dot{D}_{ij}^{s,\text{ad.valorem}}$.

To obtain the flexible gradient, $\dot{D}_{ij}^{s,\text{flex.gradient}}$, we match each observed tariff and nontariff level, t_{ij}^s and n_{ij}^s, to the closest point on the grid as defined in the previous section to get an estimate of the current level of trade costs, D_{ij}^s. In a similar vein, we match the counterfactual level of a 10-percentage-point increase in tariffs holding nontariff barriers constant to obtain the counterfactual level of trade costs, $D_{ij}^{s\prime}$. The flexible gradient is then defined as $\dot{D}_{ij}^{s,\text{flex.gradient}} = D_{ij}^{s\prime}/D_{ij}^s$. In the ad valorem specification, trade costs increase log-linearly in trade policy. Hence, $\dot{D}_{ij}^{s,\text{ad.valorem}} = \exp(\log(1+t_{ij}^{s\prime})/\exp(\log(1+t_{ij}^s))$. Note that in both specifications the relative increase in trade costs in logs induced by a 10-percentage-point increase in tariffs, $\dot{D}_{ij}^s$, depends on the current level of tariffs, respectively (as 10 percentage points mean a smaller or larger effects on tariffs in percent, depending on tariffs in the outset).

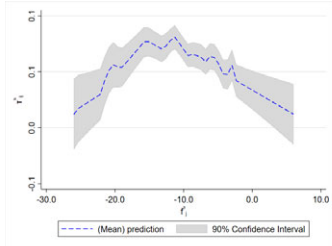
Appendix B: From first-stage estimation to the generalized propensity score

B.1 *First-stage covariates*

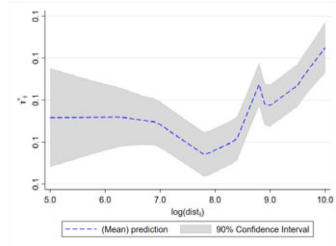
The estimation of the first stage leads to a flexible reduced-form model of trade-policy variables as a function of all the determinants in q_{ij}^s estimated by a MARS algorithm. While we abstain from an in-depth analysis of the reduced-form models for the two trade-policy variables τ_{ij}^s and η_{ij}^s, we want to point out some relationships between the



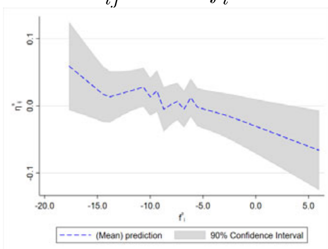
τ_{ij}^s across $\hat{f}_i^s$.



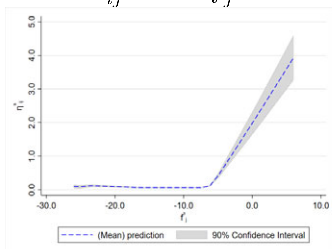
τ_{ij}^s across $\hat{f}_j^s$.



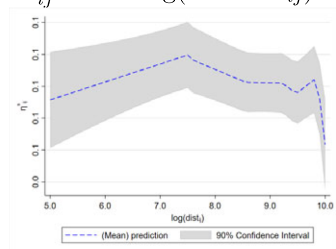
τ_{ij}^s across $\log(\text{Distance}_{ij})$.



η_{ij}^s across $\hat{f}_i^s$.



η_{ij}^s across $\hat{f}_j^s$.

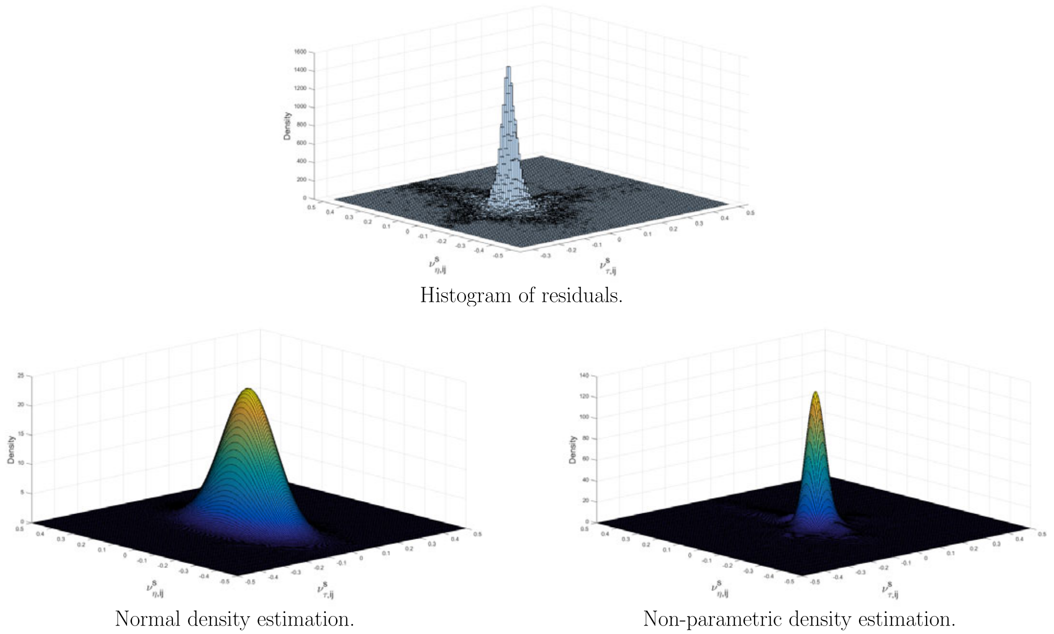


η_{ij}^s across $\log(\text{Distance}_{ij})$.

FIGURE S.1. Relationship of policy barriers and selected covariates.

country-sector fundamentals $\hat{f}_i^s$, $\hat{f}_j^s$ as well as the continuous variable contained in natural trade costs u_{ij}^s, namely log(Distance$_{ij}$), and the policy variables. We do so by evaluating the nonparametric functions, which had been selected based on the MARS algorithm between the first and the 99th percentiles of the distribution of any variable $v \in \{\hat{f}_i^s, \hat{f}_j^s; \log(\text{Distance}_{ij})\}$ separately keeping all remaining terms at their mean value. The gradient of the obtained function $\overline{\tau}(v^{\text{percentile}}, \cdot)$ and $\overline{\eta}(v^{\text{percentile}}, \cdot)$ is an estimate of the marginal effect of a change in v on $\overline{\tau}(v^{\text{percentile}}, \cdot)$ and $\overline{\eta}(v^{\text{percentile}}, \cdot)$, respectively. Note that any representation of a function containing more than 200 terms including many interactions in a two-dimensional plot is very restrictive. Hence, the associated results should be interpreted with caution.

Figure S.1 depicts the just mentioned relationships. In every panel, we plot the gradient of a trade-policy variable along with the 90% confidence bound (in gray shading) with respect to either $\hat{f}_i^s$, $\hat{f}_j^s$, or log(Distance$_{ij}$). Tariffs are slightly decreasing in the exporter's fundamentals and increasing with distance. In comparison, the effect of the importing country's—the policy-setting country's—fundamentals on tariffs is inversely u-shaped. As soon as countries have passed a certain threshold in their comparative advantage, their tariffs decrease with the level of fundamentals. In general, countries with a large comparative advantage and export potential (before factor costs) in a sector should be —and apparently are—less inclined to use tariffs for that sector than other countries. This is consistent with the notion that such countries and sectors are exposed to less competitive pressure from abroad than other ones. The latter relationship is different when it comes to nontariff barriers. The larger the comparative advantage in a sector, the higher nontariff barriers are set in a given country. This relationship could reflect the fact that competitive countries tend to impose higher standards on their products



Histogram of residuals.

Normal density estimation.

Non-parametric density estimation.

FIGURE S.2. Bivariate histogram of ν_{ij}^s and its estimated distributions.

and switch to a more hidden form of protectionism. The nontariff barriers set are, however, decreasing in the fundamentals of the exporting country. Hence, countries that are very competitive in a sector tend to face not only lower tariffs but also lower nontariff barriers abroad. Finally, nontariff barriers tend to be—on average—not systematically related to distance.

B.2 *Density of residuals from first stage*

The residuals $\nu_{ij}^s = (\nu_{\tau,ij}^s, \nu_{\eta,ij}^s)$ of the first-stage regressions serve as estimates of the two conditional (quasi-randomized) tariff and nontariff trade-policy-treatment variables whose joint density has to be estimated. The upper panel of Figure S.2 illustrates a bivariate histogram of $(\nu_{\tau,ij}^s, \nu_{\eta,ij}^s)$. For the subsequent analysis, we estimate the joint density of the latter along two alternative lines.

The first approach allows for a maximum degree of flexibility by estimating the unconditional bivariate density of ν_{ij}^s nonparametrically, following Li and Racine (2006). There, the empirical joint density is approximated by a kernel-density estimator. The key parameter governing the quality of this approximation is the bandwidth. The latter entails a trade-off between fit and smoothness of the joint density. We follow Li and Racine's (2006) suggestion in selecting the bandwidth by likelihood cross-validation and keep the bandwidth fixed over the data support. We estimate the density using a sixth-order Epanechnikov kernel.

In the second, more restrictive but customary approach, we assume a bivariate normal distribution and estimate the parameters of the distribution by maximum likelihood (see, e.g., Imai and Van Dyk (2004), Hirano and Imbens (2004), Kluve, Schneider, Uhlendorff, and Zhao (2012), for the assumption of normal densities in the context of univariate-continuous-treatment-effects estimation).

The two estimated densities along with a histogram of the empirical distribution are presented in Figure S.2. The nonparametric distribution provides the best fit to the data, especially, in fitting the asymmetric tails of the distribution. The normal density provides, however, a smoother estimate and seems less susceptible to outliers. Furthermore, estimation of the normal density is computationally less costly. We will use both types of density estimates alternatively in the following steps.

B.3 *Ensuring the validity of the joint conditional density of trade-policy variables as a compact metric of covariate similarity*

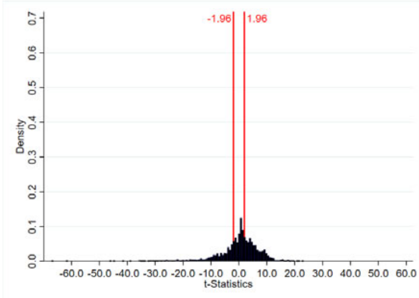
The estimated bivariate density by one of the aforementioned methods serves as an estimate of the propensity of getting randomly assigned a specific tuple of tariff and nontariff-barrier levels for any country pair and sector. The density as a compact (propensity) score can be obtained not only for observed but even for potential (hypothetical) trade-policy treatment levels. However, this compact score is meaningful only, if the covariates in q_{ij}^s are similar for all units $\{ijs\}$ with a similar level of the estimated joint density. Toward an assessment of the latter, we enforce a common support and discard observations with extreme joint-density-score values.[6] Specifically, we follow Flores et al. (2012) in defining the common support and extend their methodology to multivariate treatments.

For the present purpose, we group τ_{ij}^s and η_{ij}^s into terciles each and define $3 \cdot 3 = 9$ groups corresponding to all possible combinations of the terciles of the two trade-policy variables. We then take the median value of the two policy treatments within each group, and conditional on the covariates and the estimated parameters in (10), we predict the associated joint density based on the difference between the group-specific median value of $\{\tau_{ij}^s, \eta_{ij}^s\}$ and the conditional expectations based on (10), $\{\hat{\tau}_{ij}^s, \hat{\eta}_{ij}^s\}$, for all observations in the same group. The joint density of this difference is the predicted generalized propensity score (GPS) in the common support sample. Let us refer to this measure by CS-GPS. Using the *actual* policy treatment levels rather than the median within a group, we obtain an estimate of the original GPS. Then all observations within group k with a GPS that is outside of the range of the distribution of CS-GPS are discarded.[7] In total, we discard 273 observations outside of the common support identified by this procedure, leaving us with 92,557 country-pair-sector data points for the remainder of the analysis.[8]

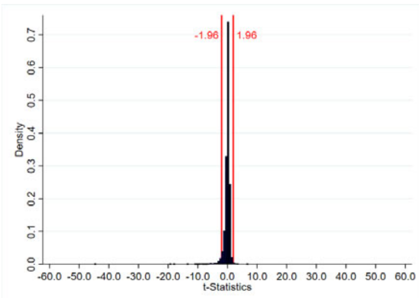
[6] See Hirano and Imbens (2004), Imbens (2004), Flores, Flores-Lagunes, Gonzalez, and Neumann (2012), for doing so in econometrically related contexts with univariate distributions.

[7] Note that the common support subsample is generally determined under the assumption of normality for the computation of both GPS and CS-GPS. This means that the common support sample is the same, irrespective of whether we compute the GPS under the assumption of normality or a nonparametric joint distribution of $\{\nu_{\tau,ij}^s, \nu_{\eta,ij}^s\}$. This is done to ensure that the treatment-effect estimates of tariff and nontariff barriers are estimated from the same subsample of the data.

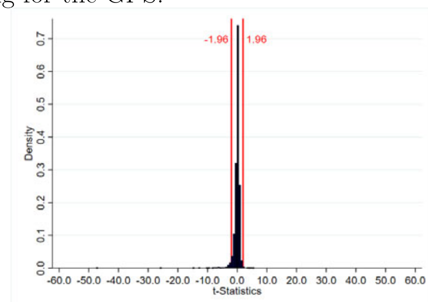
[8] We replicate our results with a substantially stricter common support definition and report the results in the Appendix.



Without accounting for the GPS.



Accounting for the GPS (normal density).



Accounting for the GPS (non-parametric density).

FIGURE S.3. Distribution of t-statistics of equality-of-means test for all covariates.

However, focusing on a common support may not be enough to ensure that for any observation with the same GPS, say $r(m, q_{ij}^s)$, the probability that the treatment for this observation corresponds to some specific level, $m_{ij}^s = m$, is independent of the observable determinants of m_{ij}^s, q_{ij}^s. We can assess this property in the spirit of Hirano and Imbens (2004) within the common support subsample of the data. For each covariate in q_{ij}^s (including the sector-level, exporting-country, and importing-country indicator variables), we may conduct a t-test under the null hypothesis that the mean of the covariate is the same across the aforementioned 9 groups. Specifically, we may perform such a test unconditionally versus conditionally on the GPS.

Figure S.3 provides a histogram plot of the t-statistics of this equality-of-means test for all covariates without and with conditioning on the two different GPS, respectively. Each panel reports the density of the t-statistics as well as the boundaries of the 95% confidence region regarding the equality of means (between two red bars). The top panel in the figure indicates that, unconditional on the GPS, many of the covariates are significantly different among the 9 groups. Hence, using a regression approach which simply conditions on the covariates in a linear fashion would miss out on nonlinear effects of the same covariates, whereby conditional nonlinear effects of the trade-policy variables on trade costs and trade flows might reflect differences in covariates, which are unaccounted for rather than effects which are attributable to trade policy. Overall, only 39% (31%) of the absolute values of the t-statistics are below 2.58 (1.96), not rejecting an equality of means at 10% (5%). Quite some of the t-statistics are even in the double digits.

In order to account for the GPS in this analysis, we split the GPS into strata such that there is a minimum of 50 observations per stratum and compare the means of all

TABLE S.1. t-statistics for all variables contained in q_{ij}^{s} across groups without conditioning on the GPS.

Group	1	2	3	4	5	6	7	8	9
$\hat{f}_{-i,-j}^{s,A}$	−31.77	6.09	6.05	−4.51	15.13	0.98	2.23	−6.21	11.88
$\hat{f}_{i}^{s}$	−28.42	11.56	12.42	−9.70	13.79	2.27	−2.65	−9.11	9.75
Contiguity$_{ij}$	−1.01	−3.75	0.02	3.50	2.76	2.84	1.66	−1.39	−4.63
Common off. lang.$_{ij}$	6.00	3.32	−2.96	1.38	−4.00	−8.99	4.62	0.68	−0.05
Common ethn. lang.$_{ij}$	3.34	1.66	−5.08	1.68	−4.06	−8.97	6.84	3.49	1.10
Colony$_{ij}$	−1.25	0.03	−2.42	3.66	−0.63	−2.29	4.93	−0.80	−1.21
Common colonizer$_{ij}$	−1.04	−5.83	−1.44	2.97	1.19	4.07	−0.59	1.81	−1.13
Current colony$_{ij}$	0.30	−5.80	−3.09	1.66	1.66	0.98	1.66	1.66	0.98
Colony$_{ij}$ (after 1945)	1.63	−0.11	0.43	3.68	−0.37	1.63	1.45	−3.85	−4.49
Same country$_{ij}$	1.02	0.68	−3.47	−2.61	−0.37	2.23	−1.75	1.71	2.57
log(Distance$_{ij}$)	8.97	20.70	9.62	−12.82	−14.05	−17.08	−8.29	0.43	12.54
$\hat{f}_{j}^{s}$	−35.37	−8.33	−9.36	2.40	8.98	−5.39	15.93	7.94	23.06

the covariates across groups within these strata. Conditioning on the density of the bivariate treatments improves the balancing of the covariates significantly, independent of the assumed functional form of the GPS—bivariate normal or nonparametric—with the nonparametric density providing a slightly better overall balancing property. The corresponding results of the conditional-means tests are reported in the lower panel of Figure S.3. This panel suggests that both the mean and the dispersion of the t-statistics are much lower than in the upper panel, with 97% (96%) of the t-statistics not rejecting an equality of the covariate means within strata but across groups at a confidence level of 10% (5%) for the normal density and 98% (96%) for the nonparametric density, respectively. Tables S.1–S.3 provide the t-statistics for all variables contained in q_{ij}^{s} without and with conditioning on the two variants of the GPS, respectively.

TABLE S.2. t-statistics for all variables contained in q_{ij}^{s} across groups conditioning on the GPS (normal density).

Group	1	2	3	4	5	6	7	8	9
$\hat{f}_{-i,-j}^{s,A}$	−1.00	0.32	0.41	−0.20	0.75	0.28	0.42	−0.42	2.62
$\hat{f}_{i}^{s}$	−0.72	1.09	1.11	−0.61	0.85	0.55	0.26	−0.42	2.62
Contiguity$_{ij}$	−0.51	−1.63	−0.41	0.08	0.02	0.09	−0.14	−0.12	−0.74
Common off. lang.$_{ij}$	0.25	−0.65	−0.79	−0.47	−0.74	−0.85	−0.09	−0.68	−0.25
Common ethn. lang.$_{ij}$	−0.31	−0.77	−1.10	−0.20	−0.79	−0.93	0.10	−0.17	−0.18
Colony$_{ij}$	0.05	−0.02	−0.20	0.33	0.03	−0.06	0.24	−0.06	−0.27
Common colonizer$_{ij}$	−0.18	−0.78	−0.09	0.39	0.15	0.37	0.23	0.16	0.11
Current colony$_{ij}$	0.12	−1.36	−0.89	0.36	0.37	0.18	0.24	0.27	0.22
Colony$_{ij}$ (after 1945)	0.03	−0.11	0.07	0.35	−0.08	0.14	−0.11	−0.07	−0.34
Same country$_{ij}$	−0.66	−0.06	−0.75	−0.74	−0.26	0.03	−0.58	0.11	0.13
log(Distance$_{ij}$)	0.36	2.23	0.81	−1.08	−0.95	−1.39	0.28	0.33	2.22
$\hat{f}_{j}^{s}$	−1.09	−0.44	−0.50	0.47	0.72	−0.11	1.42	0.73	2.97

TABLE S.3. t-statistics for all variables contained in q_{ij}^s across groups conditioning on the GPS (unconditional density).

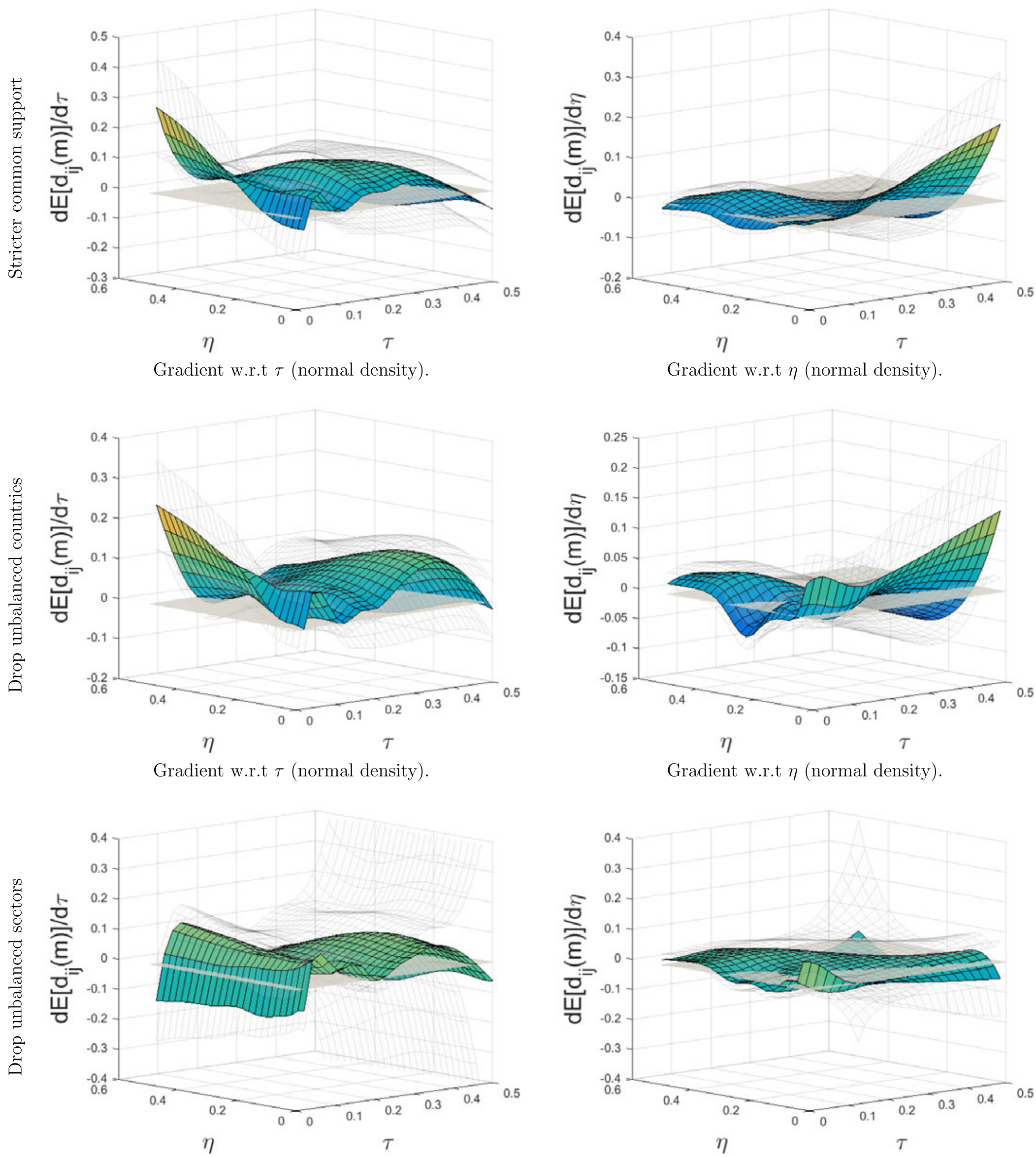
Group	1	2	3	4	5	6	7	8	9
$\hat{f}_{-i,-j}^{s,A}$	−1.11	0.49	0.31	−0.22	0.91	0.43	0.78	−0.05	4.94
$\hat{f}_i^s$	−0.79	1.23	1.08	−0.59	0.98	0.83	0.53	−0.16	4.85
Contiguity$_{ij}$	−0.49	−1.24	−0.42	0.06	0.13	0.03	−0.26	−0.19	−0.65
Common off. lang.$_{ij}$	0.09	−0.54	−0.65	−0.45	−0.81	−0.79	−0.18	−0.51	−0.52
Common ethn. lang.$_{ij}$	−0.37	−0.72	−0.96	−0.29	−0.87	−0.83	0.11	−0.18	−0.45
Colony$_{ij}$	−0.07	−0.08	−0.28	0.32	0.05	−0.04	0.16	−0.03	−0.25
Common colonizer$_{ij}$	−0.08	−0.70	−0.22	0.39	0.09	0.30	0.16	−0.03	−0.25
Current colony$_{ij}$	0.18	−0.97	−0.83	0.37	0.40	0.26	0.27	0.27	0.22
Colony$_{ij}$ (after 1945)	0.07	−0.09	0.01	0.36	−0.01	0.14	−0.13	−0.22	−0.50
Same country$_{ij}$	−0.76	−0.02	−0.69	−0.66	−0.23	−0.02	−0.40	0.05	0.23
log(Distance$_{ij}$)	0.53	2.20	0.74	−1.10	−1.07	−1.26	0.59	0.50	1.81
$\hat{f}_j^s$	−1.23	−0.33	−0.58	0.38	0.78	0.08	1.69	1.14	5.21

The relatively few covariates that remain unbalanced even after conditioning on the GPS are mainly *binary* indicator variables, which take on a unitary value in one or very few groups only. It is by design impossible to balance such covariates across all groups by conditioning on the GPS. For instance, 25 of 27 observations pertain to sector *Manufacture of veneer sheets*, which results in a t-statistic of -47.55 using the nonparametric GPS and -44.94 using the normal GPS in the respective group. Comparing Tables S.2 and S.3, we see that, despite the overall better performance of the nonparametric GPS, the GPS based on the normal density is better at balancing the continuous covariates in group 9, which includes all high trade-policy observations and most outliers from the upper panel of Figure S.2. Hence, the smoothness of the density in the tails seems to be important to balance those observations that lie in the tails of the residual distribution.

We tackle the remaining lack of balancedness by conditioning on all covariates when estimating the unit-level dose-response function (see Imai and Van Dyk (2004), Blundell and Costa Dias (2009), for this suggestion). Controlling inter alia for the unbalanced observables in the estimation of the dose-response function mitigates potential problems with the inconsistency of trade-policy treatment effects accruing to a lack of balancing of some of the covariates. Moreover, we provide a robustness check where we discard all those observations where the binary indicators could not be balanced and show that the results remain robust to this exclusion relative to controlling for the unbalanced covariates in estimation.

APPENDIX C: ADDITIONAL ROBUSTNESS

The role of covariate unbalancedness We saw that conditioning on the bivariate densities of tariff and nontariff policy barriers led to a strong reduction in the lack of balancedness (comparability) in the observables. However, such unbalancedness was not completely removed from the data for some binary indicators pointing to specific sectors for which comparison units do not exist. In the main text, we addressed this prob-



Gradient w.r.t τ (normal density). Gradient w.r.t η (normal density).

Gradient w.r.t τ (normal density). Gradient w.r.t η (normal density).

Gradient w.r.t τ (normal density). Gradient w.r.t η (normal density).

FIGURE S.1. Gradients w.r.t τ and w.r.t. η for different subsamples.

lem by conditioning on all covariates in the estimation of the trade-cost dose-response function.

Here, we pursue an alternative strategy. In the first specification, we impose a stronger common support condition. In particular, instead of creating 3 groups per treatment, we create 10 groups and ensure balancing of the GPS across all these groups. The resulting sample is considerably smaller with 67,130 observations only. In the second specification, we discard all observations, where parameters on the importing-country-specific or exporting-country-specific indicators obtain a t-statistic of larger than 2.58 in at least one of the 9 groups used in the balancing test. In the third specification, we do so for all observations with unbalanced sector indicators.

To illustrate the result, we report the gradients with respect to tariff and nontariff barriers of the three variants in each line of Figure S.1. Figure S.1 shows that the qualitative result regarding the shape of the gradients is robust to the elimination of unbalanced sectors or countries. From this, we can draw two conclusions. First, the shape of the gradients is not driven by unbalanced sectors or countries. Second, the shape of the gradients is relatively invariant to different sector or country combinations used in the estimation.

Appendix D: Additional tables

List of sectors

Table S.1. List of sectors.

ISIC 3.1	Description
0111	Growing of cereals and other crops n.e.c.
0112	Growing of vegetables, horticultural specialties, and nursery products
0113	Growing of fruit, nuts, beverage, and spice crops
0121	Farming of cattle, sheep, goats, horses, asses, mules, and hinnies; dairy farming
0122	Other animal farming; production of animal products n.e.c.
0200	Forestry, logging and related service activities
0500	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
1010	Mining and agglomeration of hard coal
1110	Extraction of crude petroleum and natural gas
1310	Mining of iron ores
1320	Mining of nonferrous metal ores, except uranium and thorium ores
1410	Quarrying of stone, sand, and clay
1421	Mining of chemical and fertilizer minerals
1429	Other mining and quarrying n.e.c.
1511	Production, processing, and preserving of meat and meat products
1512	Processing and preserving of fish and fish products
1513	Processing and preserving of fruit and vegetables
1514	Manufacture of vegetable and animal oils and fats
1520	Manufacture of dairy products
1531	Manufacture of grain mill products
1532	Manufacture of starches and starch products
1533	Manufacture of prepared animal feeds
1541	Manufacture of bakery products
1542	Manufacture of sugar
1543	Manufacture of cocoa, chocolate, and sugar confectionery
1544	Manufacture of macaroni, noodles, couscous, and similar farinaceous products*
1549	Manufacture of other food products n.e.c.
1551	Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials
1552	Manufacture of wines

(*Continues*)

Table S.1. *Continued.*

ISIC 3.1	Description
1554	Manufacture of soft drinks; production of mineral waters
1711	Preparation and spinning of textile fibers; weaving of textiles
1721	Manufacture of made-up textile articles, except apparel
1722	Manufacture of carpets and rugs
1723	Manufacture of cordage, rope, twine, and netting
1729	Manufacture of other textiles n.e.c.
1730	Manufacture of knitted and crocheted fabrics and articles
1810	Manufacture of wearing apparel, except fur apparel
1820	Dressing and dyeing of fur; manufacture of articles of fur
1911	Tanning and dressing of leather
1912	Manufacture of luggage, handbags and the like, saddlery, and harness
1920	Manufacture of footwear
2010	Sawmilling and planing of wood
2021	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, and other panels
2022	Manufacture of builders' carpentry and joinery
2023	Manufacture of wooden containers
2029	Manufacture of other products of wood; manufacture of articles of cork, straw, and plaiting materials
2101	Manufacture of pulp, paper, and paperboard
2102	Manufacture of corrugated paper and paperboard and of containers of paper and paperboard
2109	Manufacture of other articles of paper and paperboard
2211	Publishing of books, brochures, musical books, and other publications
2212	Publishing of newspapers, journals, and periodicals
2219	Other publishing
2221	Printing
2222	Service activities related to printing
2310	Manufacture of coke oven products
2320	Manufacture of refined petroleum products
2411	Manufacture of basic chemicals, except fertilizers and nitrogen compounds
2412	Manufacture of fertilizers and nitrogen compounds
2413	Manufacture of plastics in primary forms and of synthetic rubber
2422	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
2423	Manufacture of pharmaceuticals, medicinal chemicals, and botanical products
2424	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes, and toilet prepara
2429	Manufacture of other chemical products n.e.c.
2430	Manufacture of manmade fibers
2511	Manufacture of rubber tires and tubes; retreading and rebuilding of rubber tires*
2519	Manufacture of other rubber products
2520	Manufacture of plastics products
2610	Manufacture of glass and glass products
2691	Manufacture of nonstructural nonrefractory ceramic ware
2692	Manufacture of refractory ceramic products
2693	Manufacture of structural nonrefractory clay and ceramic products
2694	Manufacture of cement, lime, and plaster
2695	Manufacture of articles of concrete, cement, and plaster

(*Continues*)

Table S.1. *Continued.*

ISIC 3.1	Description
2696	Cutting, shaping and finishing of stone
2699	Manufacture of other nonmetallic mineral products n.e.c.
2710	Manufacture of basic iron and steel
2720	Manufacture of basic precious and nonferrous metals
2811	Manufacture of structural metal products
2812	Manufacture of tanks, reservoirs, and containers of metal
2813	Manufacture of steam generators, except central heating hot water boilers
2893	Manufacture of cutlery, hand tools, and general hardware
2899	Manufacture of other fabricated metal products n.e.c.
2911	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
2912	Manufacture of pumps, compressors, taps, and valves
2913	Manufacture of bearings, gears, gearing, and driving elements
2914	Manufacture of ovens, furnaces and furnace burners
2915	Manufacture of lifting and handling equipment
2919	Manufacture of other general purpose machinery
2921	Manufacture of agricultural and forestry machinery
2922	Manufacture of machine tools
2923	Manufacture of machinery for metallurgy
2924	Manufacture of machinery for mining, quarrying, and construction
2925	Manufacture of machinery for food, beverage, and tobacco processing
2926	Manufacture of machinery for textile, apparel, and leather production
2927	Manufacture of weapons and ammunition
2929	Manufacture of other special purpose machinery
2930	Manufacture of domestic appliances n.e.c.
3000	Manufacture of office, accounting, and computing machinery
3110	Manufacture of electric motors, generators, and transformers
3120	Manufacture of electricity distribution and control apparatus
3130	Manufacture of insulated wire and cable
3140	Manufacture of accumulators, primary cells, and primary batteries
3150	Manufacture of electric lamps and lighting equipment
3190	Manufacture of other electrical equipment n.e.c.
3210	Manufacture of electronic valves and tubes and other electronic components
3220	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraph
3230	Manufacture of television and radio receivers, sound or video recording, or reproducing apparatus, an
3311	Manufacture of medical and surgical equipment and orthopaedic appliances
3312	Manufacture of instruments and appliances for measuring, checking, testing, navigating, and other pur
3313	Manufacture of industrial process control equipment
3320	Manufacture of optical instruments and photographic equipment
3410	Manufacture of motor vehicles
3420	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semitrailers
3430	Manufacture of parts and accessories for motor vehicles and their engines
3511	Building and repairing of ships
3512	Building and repairing of pleasure and sporting boats
3520	Manufacture of railway and tramway locomotives and rolling stock

(*Continues*)

Table S.1. *Continued.*

ISIC 3.1	Description
3530	Manufacture of aircraft and spacecraft
3591	Manufacture of motorcycles
3592	Manufacture of bicycles and invalid carriages
3599	Manufacture of other transport equipment n.e.c.
3610	Manufacture of furniture
3691	Manufacture of jewelery and related articles
3692	Manufacture of musical instruments
3693	Manufacture of sports goods
3694	Manufacture of games and toys
3699	Other manufacturing n.e.c.
7421	Architectural and engineering activities and related technical consultancy
7494	Photographic activities
9211	Motion picture and video production and distribution

Note: * Excluded from the main analysis.

List of importers

Table S.2. List of importers.

Country			
MEX	GRC	SVN	IRL
VEN	HRV	SWE	KHM
ARG	HUN	THA	LUX
AUS	IDN	USA	LVA
AUT	ITA	BOL	MLT
BEL	JPN	CHL	MYS
BGR	LTU	CRI	NER
BRA	NLD	CYP	NGA
CAN	NZL	EST	PAN
COL	PER	ETH	PHL
CZE	POL	FIN	PRT
DEU	ROM	GBR	PRY
ECU	RUS	GHA	SGP
FRA	SVK	GTM	TGO

List of exporters

Table S.3. List of exporters.

Country			
ABW	DZA	LKA	POL
ALB	ECU	LTU	PRT
ARG	EGY	LUX	PRY
ARM	EST	LVA	PYF
AUS	ETH	MAC	ROM
AUT	FIN	MDA	RUS
AZE	FRA	MDG	RWA
BEL	GBR	MDV	SEN
BFA	GHA	MEX	SGP
BGR	GMB	MKD	SUR
BHR	GRC	MLT	SVK
BHS	GTM	MOZ	SVN
BIH	GUY	MRT	SWE
BLR	HKG	MUS	TGO
BLZ	HRV	MWI	THA
BOL	HUN	MYS	TUN
BRA	IDN	NAM	TUR
BWA	IND	NCL	TZA
CAF	IRL	NER	UGA
CAN	ISL	NGA	UKR
CHE	ISR	NIC	USA
CHL	ITA	NLD	VEN
CHN	JOR	NOR	YEM
CIV	JPN	NPL	ZAF
COL	KAZ	NZL	ZMB
CRI	KGZ	OMN	
CYP	KHM	PAK	
CZE	KNA	PAN	
DEU	KOR	PER	
DOM	LBN	PHL	

References

Adão, Rodrigo, Arnaud Costinot, and Dave Donaldson (2017), "Nonparametric counterfactual predictions in neoclassical models of international trade." *American Economic Review*, 107 (3), 633–689. [3]

Allen, Treb and Dave Donaldson (2019), "The geography of path dependence." Technical Report, Report. [1]

Anderson, James E., Mario Larch, and Yoto V. Yotov (2017), "Trade and investment in the global economy." NBER Working Papers 23757, National Bureau of Economic Research, Inc. [1]

Anderson, James E. and Eric van Wincoop (2003), "Gravity with gravitas: A solution to the border puzzle." *American Economic Review*, 93 (1), 170–192. [1]

Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare (2012), "New trade models, same old gains?" *American Economic Review*, 102 (1), 94–130. [1, 2, 3]

Blundell, Richard and Monica Costa Dias (2009), "Alternative approaches to evaluation in empirical microeconomics." *Journal of Human Resources*, 44 (3). [11]

Caliendo, Lorenzo and Fernando Parro (2015), "Estimates of the trade and welfare effects of NAFTA." *Review of Economic Studies*, 82 (1), 1–44. [1]

Costinot, Arnaud Dave Donaldson, and Ivana Komunjer (2012), "What goods do countries trade? A quantitative exploration of Ricardo's ideas." *Review of Economic Studies*, 79 (2), 581–608. [1]

Dekle, Robert, Jonathan Eaton, and Samuel Kortum (2007), "Unbalanced trade." *American Economic Review*, 97 (2), 351–355. [2, 4]

Egger, Peter H. and Sergey Nigai (2015), "Structural gravity with dummies only: Constrained ANOVA-type estimation of gravity models." *Journal of International Economics*, 97 (1), 86–99. [1]

Flores, Carlos A., Alfonso Flores-Lagunes, Arturo Gonzalez, and Todd C. Neumann (2012), "Estimating the effects of length of exposure to instruction in a training program: The case of job corps." *The Review of Economics and Statistics*, 94 (1), 153–171. [8]

Head, Keith and Thierry Mayer (2014), "Gravity equations: Workhorse, toolkit, and cookbook." In *Handbook of International Economics*, Vol. 4 (Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, eds.), 131–195, Elsevier. [1]

Hirano, Keisuke and Guido W. Imbens (2004), "The propensity score with continuous treatments." *Applied Bayesian modeling and causal inference from incomplete-data perspectives*, 226164, 73–84. [7, 8, 9]

Imai, Kosuke and David A.Van Dyk (2004), "Causal inference with general treatment regimes." *Journal of the American Statistical Association*, 99 (467). [7, 11]

Imbens, Guido W. (2004), "Nonparametric estimation of average treatment effects under exogeneity: A review." *The Review of Economics and Statistics*, 86 (1), 4–29. [8]

Kluve, Jochen, Hilmar Schneider, Arne Uhlendorff, and Zhong Zhao (2012), "Evaluating continuous training programmes by using the generalized propensity score." *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 175 (2), 587–617. [8]

Li, Qi and Jeffrey Scott Racine (2006), *Nonparametric Econometrics: Theory and Practice*. Economics Books, Vol. 1. Princeton University Press. [7]

Ossa, Ralph (2015), "WhyTtrade matters after all." *Journal of International Economics*, 97 (2), 266–277. [1]

Redding, Stephen J. (2016), "Goods trade, factor mobility and welfare." *Journal of International Economics*, 101 (C), 148–167. [1]

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