A TRADE COST APPROACH TO ESTIMATING THE ELASTICITY OF SUBSTITUTION

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Abstract

We derive an econometric specification for estimating the elasticity of substitution in import demand using a measure of international trade costs that includes tariffs and freight costs and import data that are disaggregated by product, source country, customs district of import entry, and year. The model has very practical data requirements and can be used to estimate elasticities for narrowly defined products. We demonstrate the modeling framework by estimating elasticity values using data on U.S. imports of household refrigerators, dishwashing machines, ovens, microwaves, and coffee machines.

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1 Introduction

The elasticity of substitution between varieties of a product that are imported from different countries is one of the key parameters in models of international trade. The elasticity of substitution measures the reaction of trade flows to changes in tariff rates and other trade costs.

There is a large econometric literature devoted to estimating this elasticity of substitution for different products. Within this literature, there is considerable variation in estimates, reflecting differences in data sources and estimation techniques.[1] One technique uses variation in international trade costs to identify the elasticity and a set of fixed effects to control for variation in prices and other demand factors. Hertel, Hummels, Ivanic and Keeney (2007) is a prominent example of this approach. The authors apply a trade cost and fixed effects model developed in Hummels (1999) to five-digit SITC trade data for five South American countries, the United States, and New Zealand in 1992.[2] Their estimation sample includes imports into several destination countries, and their model controls for importer fixed effects as well as exporter fixed effects. More recently, several studies have re-applied this model to district-level U.S. import data that distinguish locations within a single country. Examples include Riker (2017), Hallren and Riker (2017), and Fischer and Fox (2018). These models include district fixed effects instead of importer fixed effects. The trade cost and fixed effects approach in all of these studies is simpler and often more robust than the more elaborate system estimation approaches summarized in Ahmad et al. (2020).

In this paper, we derive an econometric specification for estimating the elasticity of substitution in demand using a measure of international trade costs that includes tariffs and freight costs and import data that are disaggregated by product, source country, customs dis-

[1] Ahmad, Montgomery and Schreiber (2020) surveys the different approaches.

[2] Additional examples of the trade cost approach to estimating elasticity values include Head and Ries (2001), Caliendo and Parro (2015), and Fontagne, Guimbard and Orefice (2019).

trict of import entry, and year. The econometric model has very practical data requirements and can be used to estimate elasticities for narrowly defined products. We demonstrate the usefulness of the modeling approach by estimating elasticity values for five types of household appliances: refrigerators, dishwashing machines, ovens, microwaves, and coffee machines.

There are several practical advantages of this approach. All of the data in the model are publicly available and easy to access on-line. The estimates can be updated using very recent trade data. The approach can generate elasticity estimates for very narrowly defined products, even individual tariff lines. The elasticity estimates can be used as parameter values in industry-specific structural simulation models – like in Riker (2017) and Hallren and Riker (2017) – or in computable general equilibrium models.[3]

The rest of the paper is organized into four sections. Section 2 derives the econometric specification. Section 3 describes the data. Section 4 uses the model to estimate the elasticity of substitution for five types of household appliances. Section 5 offers concluding remarks.

2 Econometric Specifications

First, we derive an econometric specification that is applicable when there is either non-nested or nested Constant Elasticity of Substitution demand. We start with the import demands of individual consumers and demonstrate how these can be added up to match the level of aggregation in published import statistics.

2.1 Non-Nested Constant Elasticity of Substitution

Equation (1) represents the landed duty-paid value of individual i's expenditures on imports of specific product j from country c into customs district d in year t, assuming a non-nested

[3] The default elasticities for the GTAP model are based on the trade cost approach estimates in Hertel et al. (2007).

Constant Elasticity of Substitution demands for the national varieties of the product.

$$v_{jcdit} = k_{jct} \ E_{jit} \ \left(P_{jit}\right)^{\sigma_j \ - \ 1} \ \left(p_{jct} \ f_{jcdt}\right)^{1 \ - \ \sigma_j} \ \left(s_{jdit}\right)^{-\sigma_j} \tag{1}$$

k_{jct} is a demand factor that reflects the quality of imports from country c, E_{jit} is the total expenditure of individual i on the varieties of product j from all sources, P_{jit} is the individual's Constant Elasticity of Substitution price index for product j, σ_j is the elasticity of substitution for the product, p_{jct} is the producer price of imports of product j from country c, f_{jcdt} is the international trade cost factor when these imports are shipped into customs district d, and s_{jdit} is a domestic shipping cost factor from district d to individual i. The international trade cost factor includes international freight costs, tariffs, and other import charges.[4] The value of consumer i's expenditure on these imports is $(v_{jcit} \ s_{jdit})$.

We do not observe the imports of individuals in published import statistics, but we do observe total imports that enter district d, so the next step is to sum over all of the individuals that are supplied imports of product j through district d.

Equation (2) is the landed duty-paid value of all imports of product j from country c into district d in year t, summed across individual consumers.

$$v_{jcdt} = \left[k_{jct} \ \left(p_{jct}\right)^{1 \ - \ \sigma_j}\right] \ \left[\left(f_{jcdt}\right)^{1 \ - \ \sigma_j}\right] \ \left[\sum_{i \ \in \ \omega_{jdt}} E_{jit} \ \left(P_{jit}\right)^{\sigma_j \ - \ 1} \ \left(s_{jdit}\right)^{-\sigma_j}\right] \tag{2}$$

ω_{jdt} represents the set of all individuals that are supplied by imports of product j through district d in year t.[5]

Equation (3) is an econometric specification derived by log-linearizing equation (2) and

[4] Specifically, the international trade cost factor is measured using the ratio of the landed duty-paid value of imports to their customs value.

[5] Riker (2017) is an example of a CES demand system in which there are disjoint sets of consumers served by the different import districts. Riker (forthcoming) is an example of a "love of variety" constant elasticity of substitution demand system in which all consumers purchase from every import district. Both of these demand specifications are consistent with equation (2).

adding a term ϵ_{jcdt} that captures measurement error in $\ln v_{jcdt}$ and any omitted explanatory variables. The product j-specific elasticity σ_j can be estimated by pooling over the three other dimensions of variation in the import data: source country, district, and year.

$$\ln v_{jcdt} = \alpha_{jct} \; + \; \beta_j \; \ln f_{jcdt} \; + \gamma_{jdt} \; + \epsilon_{jcdt} \tag{3}$$

Equation (4) is the value of the elasticity of substitution.

$$\sigma_j = 1 \; - \; \beta_j \tag{4}$$

Equations (5) and (6) define the country-year and district-year fixed effects in the model.

$$\alpha_{jct} = \ln \left[\; k_{jct} \; \left(p_{jct} \right)^{1 \; - \; \sigma_j} \; \right] \tag{5}$$

$$\gamma_{jdt} = \ln \left[\; \sum_{i \; \in \; \omega_{jdt}} E_{jit} \; \left(P_{jit} \right)^{\sigma_j \; - \; 1} \; \left(s_{jdit} \right)^{-\sigma_j} \; \right] \tag{6}$$

The country-year and district-year fixed effects are very practical: they reduce the data requirements of the model and control for variables that would be difficult to directly measure, including the price index, producer prices, and total expenditure terms. The econometric specification in equation (3) does not try to identify the individual elements within these fixed effects. The reason that we derived the specification from individual consumer demands is to demonstrate that even if there is significant heterogeneity in E_{jit}, P_{jit}, and s_{jdit} across individual consumers due to differences in their location, we do not need to measure this heterogeneity in order to estimate σ_j.

2.2 Nested Constant Elasticity of Substitution

Next, we consider an alternative demand structure with imports from all source countries included within a Constant Elasticity of Substitution nest. The elasticity of substitution within this nest is θ_j for product j. The elasticity of substitution between domestic products and the Constant Elasticity of Substitution composite of imports is $\sigma_j > \theta_j$. In this case, β_j is tied to the elasticity of substitution *within the nest*, known as the "micro" elasticity of substitution in Feenstra, Luck, Obstfeld and Russ (2017).

$$\theta_j = 1 \ - \ \beta_j \tag{7}$$

In a nested Constant Elasticity of Substitution version of the model, the district-year fixed effects control for a different set of price index terms.

$$\gamma_{jdt} = \ln \left[\sum_{i \ \in \ \omega_{jdt}} E_{jit} \ \left(PDM_{jit}\right)^{\sigma_j \ - \ 1} \ \left(PM_{jit}\right)^{\sigma_j \ - \ \theta_j} \left(s_{jdit}\right)^{-\theta_j} \right] \tag{8}$$

PM_{jit} is the Constant Elasticity of Substitution price index for imports from different countries, and PDM_{jit} is the Constant Elasticity of Substitution price index between the domestic product and a Constant Elasticity of Substitution composite that represents the import nest. The same reduced-form econometric specification in equation (3) is applicable when there is non-nested or non-nested Constant Elasticity of Substitution demand. The fixed effects just capture different factors, and the estimated β_j parameter has a different structural interpretation.

3 Data Sources

The source of the import data is the U.S. International Trade Commission's Dataweb at `https://dataweb.usitc.gov/`. The landed duty-paid value (LDPV) of imports for consumption is equal to the customs value (CV) of the imports plus international freight costs, other import charges, and calculated import duties. The variable $\ln v_{jcdt}$ in equation (3) is the natural log of the LDPV. The trade cost factor $\ln f_{jcdt}$ is the natural log of the ratio of LDPV to CV.

We recommend estimating the models for detailed rather than aggregate products. This mitigates any differences in the product composition of imports entering different districts in a particular year. It reduces variation in country-specific producer prices that will not be absorbed by the country-year fixed effects.

We focus on six-digit Harmonized Tariff Schedule (HTS) codes for five types of household appliances. Table 1 reports the value of U.S. imports of the five products.

Table 1: U.S. Imports of Household Appliances in 2019

HTS Code	Description	Landed Duty-Paid Value in Billions of Dollars
841821	Refrigerators	4.08
842211	Dishwashing Machines	3.42
851650	Microwave Ovens	12.72
851660	Electric Ovens and Ranges	12.83
851671	Electric Coffee and Tea Makers	11.15

We can decompose the international trade cost factor f_{jcdt} into two rates, a tariff rate $\left(\frac{LDPD-CIF}{CV}\right)$ and an international freight rate $\left(\frac{CIF-CV}{CV}\right)$, so $f_{jcdt} = 1 + \frac{LDPV-CIF}{CV} + \frac{CIF-CV}{CV}$. Table 2 reports the variation in these two rates for each of the five products for the period 2010–19. The standard deviations indicate that most of the variation in f_{jcdt} comes from the international freight rates, which vary significantly across the district-country pairs. The international freight rates are much larger than the tariff rates, and they have more variation *within product*.

Table 2: International Trade Cost Factors

	HTS 841821	HTS 842211	HTS 851650	HTS 851660	HTS 851671
Mean of $\left(\frac{LDPV}{CV}\right)$	1.088	1.088	1.092	1.077	1.087
Standard Deviation of $\left(\frac{LDPV}{CV}\right)$	0.116	0.075	0.083	0.108	0.065
Mean of $\left(\frac{LDPV-CIF}{CV}\right)$	0.005	0.021	0.018	0.009	0.035
Standard Deviation of $\left(\frac{LDPV-CIF}{CV}\right)$	0.027	0.012	0.006	0.019	0.012
Mean of $\left(\frac{CIF-CV}{CV}\right)$	0.084	0.067	0.074	0.068	0.052
Standard Deviation of $\left(\frac{CIF-CV}{CV}\right)$	0.112	0.073	0.084	0.106	0.064

4 Estimates for Five Household Appliances

Following Hertel et al. (2007), we use Ordinary Least Squares to estimate the parameters in equation (3) for each of the five types of appliances.[6] Table 3 reports product-specific point estimates of σ_j (or θ_j) and robust standard errors. All of the estimates are based on a panel of imports for the period 2010–19 that are disaggregated by six-digit HTS code, source country, customs district, and year. The model for each product includes a full set of country-year and district-year fixed effects.

As a sensitivity analysis, we also considered the possibility that the tariff rates included in the international trade cost factor might be endogenously determined, leading to a potential bias in the estimated value of σ_j. We re-estimated the parameters in equation (3) using a measure of f_{jcdt} that includes international freight costs and import charges $\left(\frac{CIF-CV}{CV}\right)$ but not tariff rates $\left(\frac{LDPV-CIF}{CV}\right)$. The drawback of this alternative measure is that it may lead

[6]Alternatively, the parameters can be estimated using a Poisson Pseudo-Maximum Likelihood estimator if there are heterogeneity concerns.

Table 3: Estimates of the Elasticity of Substitution by Product

	HTS 841821	HTS 842211	HTS 851650	HTS 851660	HTS 851671
Point Estimate	7.50	9.38	6.11	7.03	9.80
Robust Standard Error	(1.37)	(1.79)	(1.54)	(0.72)	(1.31)
Country-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
District-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
R-Squared	0.700	0.748	0.797	0.639	0.756
Number of Observations	1,198	887	987	2,908	1,838

to omitted variable bias in the estimate of the elasticity of substitution. Table 4 reports the Ordinary Least Squares estimates using this alternative measure of f_{jcdt}. The estimates in Table 4 are very similar to their counterparts in Table 3, and this suggests that endogeneity bias is not a significant problem.

Table 4: Econometric Estimates with Alternative Measure of f_{jcdt}

	HTS 841821	HTS 842211	HTS 851650	HTS 851660	HTS 851671
Point Estimate	7.71	9.17	5.96	6.33	9.78
Robust Standard Error	(1.39)	(1.77)	(1.53)	(0.67)	(1.29)
Country-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
District-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
R-Squared	0.702	0.747	0.797	0.636	0.756
Number of Observations	1,198	887	987	2,908	1,838

5 Conclusions

The trade cost approach to estimating the elasticity of substitution in import demand is easy to implement and has many practical implications. The model estimates reasonably precise elasticity values for specific products by pooling over the other dimensions in the import data (country, district, and year). There are few data requirement because many relevant variables are absorbed in the fixed effects. The estimated elasticity values can be useful in structural simulation models that are either industry-specific or economy-wide. They can simulate the impact of shocks to tariffs and freight costs, but also foreign production costs on a variety of outcomes. They can be used to quantify resulting changes in flows, import prices, domestic production levels, and employment. Riker (2017) and Hallren and Riker (2017) are examples of simulations that apply elasticity of substitution values estimated using the trade cost and fixed effects approach.

References

Ahmad, S., Montgomery, C. and Schreiber, S. (2020). A Comparison of Armington Elasticity Estimates in the Trade Literature. U.S. International Trade Commission, Economics Working Paper 2020-04-A.

Caliendo, L. and Parro, F. (2015). Estimates of the Trade and Welfare Effects of NAFTA, *Review of Economic Studies* **82**(1): 1–44.

Feenstra, R., Luck, P., Obstfeld, M. and Russ, K. (2017). In Search of the Armington Elasticity. NBER Working Paper 20063.

Fischer, C. and Fox, A. K. (2018). How Trade Sensitive are Energy-Intensive Sectors?, *AEA Papers and Proceedings* **108**: 130–135.

Fontagne, L., Guimbard, H. and Orefice, G. (2019). Product-Level Trade Elasticities. CEPII Working Paper No. 2019-17.

Hallren, R. and Riker, D. (2017). A U.S. Regional Model of Import Competition and Jobs. U.S. International Trade Commission, Economics Working Paper 2017-02-A.

Head, K. and Ries, J. (2001). Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade, *American Economic Review* **91**(4): 858–876.

Hertel, T., Hummels, D., Ivanic, M. and Keeney, R. (2007). How Confident Can We Be of CGE-Based Assessments of Free Trade Agreements, *Economic Modelling* **24**(4): 611–635.

Hummels, D. (1999). Toward a Geography of Trade Costs. GTAP Working Paper No. 17, Center for Global Trade Analysis, Purdue University, West Lafayette, IN.

Riker, D. (2017). The Effect of Furniture Imports from China on Employment in U.S. Regions. U.S. International Trade Commission, Economics Working Paper 2017-08-A.

Riker, D. (forthcoming). Estimating U.S. Import Penetration in Sub-National Regions, *Journal of International Trade & Economic Development* .