Is the Armington Elasticity Really Constant across Importers?*

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Abstract

This paper shows that the Armington elasticity, which refers to both the elasticity of substitution across goods and the price elasticity of demand, systematically changes from one importer country to another one in an international trade context. Then a natural question to ask is "What determines the Armington elasticity?" The answer comes from the distinction between the elasticity of demand with respect to the destination price (i.e., the Armington elasticity) and the elasticity of demand with respect to the source price. Under additive trade costs, it is shown that the former increases in the latter and the trade costs, and it decreases in the source prices. The empirical results using the US exports data support this relation by showing that the Armington elasticity in fact increases in trade costs and decreases in source prices; hence, it is more likely to have a constant elasticity of demand with respect to the source price rather than a constant Armington elasticity.

JEL Classification: F12, F13, F14

Key Words: Armington Elasticity; International Trade; Trade Ratios; State Exports; the United States

1. Introduction

Many trade models have a common feature that countries (or regions) produce and trade differentiated goods that are to some extent substitutable for each other. In these models, the constant elasticity of substitution (CES) between the products of different countries (i.e., the Armington (1969) elasticity) is a critical parameter for determining the behavior of trade flows and international prices. As Ruhl (2008) points out, the importance of this parameter has manifested in two of the leading branches of international economics: the international business cycle literature that seeks to understand the high frequency fluctuations in macroeconomic aggregates, and the static applied general equilibrium literature that focuses on explaining the patterns of trade and the effects of trade policy. But, is this critical parameter really a constant?

This paper investigates whether or not the Armington elasticity systematically changes from one importer country to another one in the context of international trade. For instance, when the U.S. state exports to the rest of the world are considered, the Armington elasticity corresponds to the CES between the products of different states. While some U.S. partner countries may have higher Armington elasticities, some others may have lower elasticities. Then a natural question to ask is "What determines the difference between these elasticities?" In the context of Armington aggregators, under the assumption of a large number of varieties (i.e., the assumption that the individual variety prices have zero effects on the aggregated price index of all varieties), the constant elasticity of substitution is equal to the price elasticity of demand. Hence, anything that affects the price elasticity of demand should also affect the elasticity of substitution across goods. Then, what determines the price elasticity of demand?

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Under additive trade costs, I show that the price **e**lasticity of **d**emand with respect to the **d**estination price (EDD) can be decomposed into two parts: the **e**lasticity of **d**emand with respect to the **s**ource price (EDS) and the **e**lasticity of **d**emand with respect to the **t**rade costs (EDT). I show that EDD is the sum of EDS and EDT. I also show that EDD is increasing in EDS and trade costs, while it is decreasing in source prices. In order to test the relation between EDD, EDS, trade costs, and source prices, I use the U.S. export data that cover the exports from each state of the United States to 230 countries around the globe between 1999-2007. The empirical analysis support the view that EDD increases with trade costs and decreases with source prices. This result implies that while it is more likely to have a constant EDS across countries, EDD is not constant, and it changes from one importer country to another, mostly due to trade costs through EDT. Since EDD is equal to the elasticity of substitution in the context of Armington aggregators, this result also implies that the elasticity of substitution is not constant as opposed to the CES assumption that is commonly used in the trade literature.

The story behind this is as follows. It is known that the importer's demand for the exporter's good depends on the source price and the trade costs. However, the formation of elasticity is the key here. For instance, as in the spatial pricing theory, the importers may form their elasticities as they are at the source, although their demand for exports still depends on trade costs.[1] In such a case, different countries may have the same EDS. This makes sense when importers shop in the exporter country by considering the prices at the source; i.e., by forming their demands according to the source prices. The trade costs are only additional costs that importers have to pay, and they are aware of this issue through their demand functions. The mirror image of this example in the context of individual behavior can be related to the story that individuals form their elasticities according to the source prices that they face at the market (e.g., the shopping centers). The additional trade costs related to going to the market (e.g., depreciation of the cars, gas prices, auto insurance costs, driving risks) are only additional costs that have to be paid by the individuals. In this context, given that an individual is going to shop from a particular shopping center, that individual compares only the source prices; thus, the elasticity measure should be formed with respect to the source prices at the shopping center. When I generalize this story to the context of U.S. state exports, given a country is going to import a good from the U.S., that country compares only the source prices in different states; thus the elasticity should be formed with respect to the source prices at different states.

In terms of modelling, I first show that EDD is the sum of EDS and EDT for any type of demand function. I also show that EDD is increasing in EDS and trade costs, while it is decreasing in the source prices, again for any type of demand function. Then, I continue with introducing a partial equilibrium trade model. I assume that each country has a distinct import demand for different countries' goods (represented by a subutility). For instance, the United Kingdom (U.K.) has a certain demand (and a corresponding elasticity of demand) for the United States (U.S.) goods, while Germany has a different demand (and a corresponding elasticity of demand) for the very same U.S. goods. The demand of each importer country is represented by an Armington aggregator which is a combination of different goods imported from the U.S. Each country also has a distribution firm who collects the import demand from the country and goes for a shopping to the exporter country. In terms of my example, there is a distribution firm in the U.K. who goes for a shopping to the U.S. Since the distribution firm collects demands from the U.K., the demand of the distribution firm in the U.S. should be exactly equal to the demand of the individuals in the U.K. under certain conditions. While the individuals in the U.K. face destination (i.e., the U.K.) prices, the U.K. distribution firm faces the source (i.e., the U.S.) prices in the U.S. According to this setup, the individuals in the U.K. change their demand according to the destination prices, and thus, their behavior is represented by an EDD. However, since the U.K. distribution firm is at the source (i.e., the U.S.), it changes its demand according to the source prices, and thus, its behavior is represented by an EDS. It is verified that EDD is in fact a function of EDS under an Armington aggregator. In terms of the estimation strategy, the tested relation is the one showing that EDD is increasing in EDS and trade costs and that it decreases in the source prices. The empirical analysis supports this relation by having very high explanatory powers. Overall, this paper challenges mostly the CES type aggregators that are commonly used in the international trade and macroeconomics literature by showing that the

[1] See Greenhut et al. (1987) for an excellent analysis of imperfect competition in the context of spatial pricing.

Armington elasticity is not constant across importer countries.

Related Literature

In this subsection, I briefly describe how this paper relates to its closest antecedents. Since the constant elasticity of substitution is equal to the price elasticity of demand in the context of Armington aggregators under the assumption of large number of varieties, the studies that have focused on both types of elasticities are depicted here. The Dixit-Stiglitz (1977) model is a pioneering one that has been widely used or extended in many literatures such as international trade, macroeconomics, and growth and development.[2] However, most of the time, the Dixit-Stiglitz model has been used with a complementary assumption of CES. But is the Armington elasticity is really constant across importers? Because, if it is, the elasticity of demand, the elasticity of substitution, markups and prices are all invariant from one importer country to another. But is it really the case that there are constant markups and prices across all importers?

Older empirical studies have focused on how the elasticity changes by the origin country of exports. In particular, since Tinbergen's (1946) pioneering article on the measurement of elasticities in international trade more than half of a century ago, there have been many studies designed to measure the relationship between changes in relative prices and changes in relative exports.[3] Most of these empirical studies have estimated the relation between the volume of trade and the relative price levels across countries. These studies were thinking of the elasticity of the demand for imported units only of a given commodity; or of the elasticity of the demand supplied by one specific country. More recent empirical studies also show evidence for different elasticities of substitution values for different goods.[4]

Besides that empirical literature, theoretical studies based on optimal tariff rates show that the elasticities of substitution play an important role in determining the optimal tariff rates set by an importer country.[5] Although these theoretical papers show that there can be a positive relation between the tariff rates and elasticity of substitution under certain parameters, they don't say anything related to a relation between overall trade costs and the elasticity of substitution. Moreover, the relation that they are considering is mostly due to a unique causation: a change in the elasticity of substitution causes a change in the optimal tariff rates. They don't tell us anything about how the elasticity of substitution is determined. They take the elasticities as given and find the optimal tariff rates accordingly.

However, none of these studies have focused on how the Armington elasticity changes by the importer country. This paper considers the Armington elasticity across exports of the U.S. states in 230 different countries around the globe. I not only show that the Armington elasticity is variable across these 230 countries, but also show that the difference in terms of elasticities can be explained by the source prices and trade costs. For instance, I show that the elasticity of substitution in the U.K. for exports of different U.S. states is different from the one in Canada, and this difference, on average, can be explained by the difference in the source prices (due to price discrimination of the U.S. exporters) and trade costs (which is different across the U.K. and Canada).

Nevertheless, this paper is not the first one analyzing variable elasticities across importers. There are studies in which market entry affects the elasticity of demand. Most of the trade theory literature with this feature has emphasized oligopoly and homogeneous goods as in Brander and Krugman (1982).[6] The literature on pricing-to-market is another one that shows evidence for varying elasticities. This literature has shown that the same goods are priced with different markups and thus have different price elasticities of demand across importing markets.[7] For instance, Feenstra (1989) and Knetter (1993) belonging to this literature focus on the movements along the

[2] See Gordon (1990) and Matsuyama (1995) for literature surveys.

[3] See Chang (1948), Polak (1950), Kreinin (1967), Kravis and Lipsey (1972, 1975), Richardson (1972, 1973), Hickman and Lau (1973), Chou and Buongiorno (1983), among many others.

[4] See Hummels (2001), Head and Ries (2001), Harrigan (1996), Feenstra (1994), Romalis (2007), Broda and Weinstein (2006), Gallaway et al. (2003), among many others, for different elasticity measures for different goods.

[5] See Johnson(1953-1954), Gorman (1958), more recently Syropoulos (2002), Zissimos (2008), among others,

[6] Broda and Weinstein (2006) empirically show how elasticities change across importers. In connection with this literature, more recently, Dekle et al. (2008) have shown that there is a difference between short-run and long-run elasticities due to trade stickiness.

[7] See Goldberg and Knetter (1997) for an excellent literature review.

same, non-CES, demand curves so that variation in quantities caused by tariff or exchange rate shocks yields variation in the elasticity of demand. However, this literature doesn't provide any systematic explanation for the difference in elasticities across importers. More recently, Hummels and Lugovskyy (2008; HL henceforth) attempt to bridge this gap by showing that the Armington elasticity increases in importer GDP and decreases in importer GDP per capita. However, their log-linear empirical approach can be criticized because of the following possible reasons. First, there can be multicollinearity between importer GDP and importer GDP per capita in such a regression. In particular, according to my data covering the period between 1999-2007 (i.e., 230 countries around the globe), the correlation coefficient between (log) GDP and (log) GDP per capita is around 0.48 (on average) in a typical year. Although this correlation coefficient is below 0.70, which is the threshold value as a rule of thumb to be warned of potential problems with multicollinearity (see Anderson et al., 2006), the overall quality of the results may be affected. Second, estimating log-linear expressions by using ordinary least squares (OLS) is highly criticized. In particular, as Santos Silva and Tenreyro (2006), and Henderson and Millimet (2008) suggest, under heteroskedasticity, the parameters of log-linearized models estimated by OLS may lead to biased estimates; thus, an alternative estimation method, Pseudo-Maximum Likelihood (PPML), should be preferred. My paper follows this suggestion as a robustness analysis besides using OLS.

Besides these possible problems, the explanatory power of HL is very low (i.e., R^2 value is around 0.17), which means that much of the variation in Armington elasticities cannot be explained with only importer GDP and importer GDP per capita. When I replicate the empirical analysis of HL by using my data (i.e., by running a regression including importer GDP and importer GDP per capita), I show that the R^2 value is around 0.18, which is very close to what HL have. Fortunately, the approach that I use in this paper allows me to have a richer list of variables in such a regression including trade costs, import volumes, income levels, exchange rates, and purchasing power parity. For sure, in order to control for a possible multicollinearity problem, I don't include correlated variables (e.g., import volumes and income levels) into the regression at the same time. My regression analyses have R-bar sqd. values up to 0.74 by using OLS and 0.96 by using PPML, which are much higher compared to the ones in HL.

Plan of the Paper

The rest of the paper is organized as follows. Section 2 depicts the connection between EDD, EDS, and EDT. Section 3 introduces a simple trade model. Section 4 describes the data. Section 5 provides insights and depicts the estimation methodology. Section 6 gives the empirical results. Section 7 concludes.

2. Elasticity of Substitution

I start with showing that, under additive trade costs, EDD is the sum of EDS and EDT. I also show that EDD is increasing in EDS and trade costs, and it is decreasing in source prices, for any type of demand function. Consider the following general type demand function:

$$Q = f(P + \tau)$$

where Q is the quantity demanded, P is the source price, and τ is representing the trade costs. According to this demand function, EDD is given by:

$$\begin{aligned}\text{EDD} &= -\frac{dQ}{d(P+\tau)}\frac{P+\tau}{Q} \\ &= -\frac{df(P+\tau)}{d(P+\tau)}\frac{P+\tau}{Q}\end{aligned}$$

Similarly, EDS and EDT are given by:

$$\begin{aligned} \text{EDS} &= -\frac{dQ}{dP}\frac{P}{Q} \\ &= -\frac{df\left(P+\tau\right)}{dP}\frac{P}{Q} \\ &= -\frac{df\left(P+\tau\right)}{d\left(P+\tau\right)}\frac{d\left(P+\tau\right)}{dP}\frac{P}{Q} \\ &= -\frac{df\left(P+\tau\right)}{d\left(P+\tau\right)}\frac{P}{Q} \end{aligned}$$

and

$$\begin{aligned} \text{EDT} &= -\frac{dQ}{d\tau}\frac{\tau}{Q} \\ &= -\frac{df\left(P+\tau\right)}{d\tau}\frac{\tau}{Q} \\ &= -\frac{df\left(P+\tau\right)}{d\left(P+\tau\right)}\frac{d\left(P+\tau\right)}{d\tau}\frac{\tau}{Q} \\ &= -\frac{df\left(P+\tau\right)}{d\left(P+\tau\right)}\frac{\tau}{Q} \end{aligned}$$

The last lines of these expressions imply that:

$$\text{EDD} = \text{EDS} + \text{EDT}$$

which means that EDD can in fact be decomposed into EDS and EDT.

Moreover, by using the expressions for EDD and EDS, I can write:

$$\text{EDD} = \left(\frac{P+\tau}{P}\right)\text{EDS} \tag{2.1}$$

which means that EDD increases in EDS and trade costs, and it decreases in the source prices, *ceteris paribus*. Here there a couple of possibilities. One of them is that EDD is constant and EDS is variable across importer countries. According to Equation 2.1, this would imply that the Armington elasticities are constant across importer countries. However, as I will show below, the data don't support this possibility. Another possibility is that EDS is constant and EDD is variable across importer countries. According to Equation 2.1, this would imply that the Armington elasticities increase in the trade costs and decreases in source prices. As I will show below, the data support this second possibility. Hence, it is more likely to have a constant EDS and a variable EDD across importer countries.

3. The Model

I model an economy consisting of a finite number of countries. Each country may (or may not) import goods from all other countries. Since I only care about the partial equilibrium bilateral trade implications of my model, in many instances, I skip the irrelevant details of the model in order to keep it as simple as possible.[8]

In the model, generally speaking, $H_{a,b}^{c}$ stands for the variable H, where a is the importer country (i.e., the destination), b is the good, and c is the exporter country (i.e., the source). While the model considers the individuals and the distribution firm in the importer country, it considers only the source prices in the exporter country.

3.1. Individuals of the Importer Country

The representative agent in country a maximizes utility $U\left(C_a^1, C_a^2, ...C_a^N\right)$ where C_a^1 is a composite index of goods imported from country 1, C_a^2 is a composite index of goods imported from country 2, and so on. In country a, the

[8] A general equilibrium framework is not necessary in my analysis. It would only complicate the model with unnecessary details.

composite index of goods imported from country k is given by the following CES function:

$$C_a^k \equiv \left(\sum_i (\beta_a \gamma_k \theta_i)^{\frac{1}{\eta_a^k}} \left(C_{a,i}^k\right)^{\frac{\eta_a^k - 1}{\eta_a^k}} \right)^{\frac{\eta_a^k}{\eta_a^k - 1}} \tag{3.1}$$

where $C_{a,i}^k$ is good i imported from country k (e.g., $C_{a,i}^k$ is good i is produced in region i of country k); $\eta_a^k > 1$ is the Armington elasticity in country a for the goods imported from country k; β_a is a destination (i.e., importer) specific taste parameter; γ_k is a source (i.e., exporter) specific taste parameter; and finally, θ_i is a good specific taste parameter. While having only one taste parameter, which is good, destination, and source specific, is common in the literature, decomposing it into γ_k, β_a and θ_i is new in this paper.[9] In particular, γ_k, β_a and θ_i can be used as fixed effects in a regression analysis; i.e., their multiplication represents a unique taste parameter between regions a and k in terms of good i.

The optimal allocation of any given expenditure yields the following demand functions:

$$C_{a,i}^k = \beta_a \gamma_k \theta_i \left(\frac{P_{a,i}^k}{P_a^k} \right)^{-\eta_a^k} C_a^k \tag{3.2}$$

where $P_{a,i}^k$ is the price of good i exported from country k in country a, and $P_a^k \equiv \left(\sum_i \beta_a \gamma_k \theta_i \left(P_{a,i}^k\right)^{1-\eta_a^k} \right)^{\frac{1}{1-\eta_a^k}}$ is the price index of the goods in country a exported from country k. It is implied that $P_a^k C_a^k = \sum_i P_{a,i}^k C_{a,i}^k$.

3.2. Distribution Firm of the Importer Country

The representative distribution firm in country a collects demand for imports in country a and shops in the exporter country according to the collected demand. The distribution firm uses two inputs: the imported good, and the transportation services. These inputs are perfect complements by definition; i.e., the demand of the distribution firm for the transportation services increases with its demand for the imported good one-to-one. Under the assumption of perfectly competitive distribution firms (i.e., price equals marginal cost), this implies that, if there is a trade between countries, it is subject to an additive trade cost:

$$P_{a,i}^k = P_{k,i}^k + \tau_{a,i}^k \tag{3.3}$$

where $P_{k,i}^k$ is the price of good i in country k (i.e., the source); $\tau_{a,i}^k > 0$ is a good specific net transportation cost from country k to country a.

Since the distribution firm shops in the exporter country according to the collected demand, the supply of the distribution firm for any imported good (say, for $C_{a,i}^k$) is also given by 3.2. However, different from the individuals in country a who face the destination price $P_{a,i}^k$, the distribution firm faces the source price $P_{k,i}^k$ while shopping in the exporter country (i.e., country k). This implies that the elasticity of demand of the distribution firm should be with respect to the source price. In order to show this, substitute Equation 3.3 into Equation 3.2 to obtain an expression for the market clearing condition of each imported good in the destination country:

$$S_{a,i}^k = C_{a,i}^k = \beta_a \gamma_k \theta_i \left(\frac{P_{k,i}^k + \tau_{a,i}^k}{P_a^k} \right)^{-\eta_a^k} C_a^k \tag{3.4}$$

where $S_{a,i}^k$ is the supply of the distribution firm. Since the market clearing condition is satisfied in the destination country, it should be the case that the total revenue of the firm should be equal to the total expenditure of the individuals:

$$P_{k,i}^k S_{a,i}^k + \tau_{a,i}^k S_{a,i}^k = \left(P_{k,i}^k + \tau_{a,i}^k\right) C_{a,i}^k$$

[9] Distinguishing between good, destination and source specific taste parameters has useful properties in terms of my estimation.

Under the assumption of perfectly competitive distribution firm, the profit function can be written as:

$$\pi = P_{k,i}^{k} S_{a,i}^{k} + \tau_{a,i}^{k} S_{a,i}^{k} - P_{k,i}^{k} D_{a,i}^{k} - \tau_{a,i}^{k} D_{a,i}^{k} = 0$$

where $D_{a,i}^{k}$ is the demand of the distribution firm for both the imported good and the transportation services under the assumption of perfectly complementary inputs. It is implied by these equations that $D_{a,i}^{k} = C_{a,i}^{k}$. In other words, the input (i.e., the imported good) demand of the distribution firm is exactly equal to the import demand of the individuals in the importer country. Nevertheless, although the input demand is equal to $C_{a,i}^{k}$, the price of the input is $P_{k,i}^{k}$. That is to say, the distribution firm is going to form its elasticity of demand for the imported good with respect to this source price.

Notice that the distribution firm has an input demand also for transportation services. Analogously, although the input demand for transportation services is equal to $C_{a,i}^{k}$, the price of this input is $\tau_{a,i}^{k}$. That is to say, the distribution firm is going to form its elasticity of demand for the transportation services with respect to $\tau_{a,i}^{k}$.

Elasticity of Substitution

According to Equation 3.4 and $D_{a,i}^{k} = C_{a,i}^{k}$, the demand of the distribution firm for the imported good is given by:

$$C_{a,i}^{k} = \beta_a \gamma_k \theta_i \left(\frac{P_{k,i}^{k} + \tau_{a,i}^{k}}{P_a^{k}} \right)^{-\eta_a^{k}} C_a^{k} \tag{3.5}$$

Since I have a CES function in Equation 3.1, by definition, the elasticity of demand for the imported good with respect to the destination price (i.e., EDD) is given by η_a^{k}. But, what about EDS? It can easily be calculated as:

$$\varepsilon^{k} = \frac{P_{k,i}^{k} \eta_a^{k}}{P_{k,i}^{k} + \tau_{a,i}^{k}} \tag{3.6}$$

Note that ε^{k} (i.e., EDS) is the same for all countries that import from country k, because all distribution firms (each corresponding to a different country) are assumed to act in a similar way after facing the very same prices at the source. Also note that, in a special case in which trade costs are equal to zero, $\varepsilon^{k} = \eta_a^{k}$.

Because of the assumption of perfectly complementary inputs, the demand of the distribution firm for the transportation services is also given by Equation 3.5. Since the distribution firm forms its elasticity of demand for the transportation services with respect to $\tau_{a,i}^{k}$, EDT is can be calculated as:

$$\chi_a^{k} = \frac{\tau_{a,i}^{k} \eta_a^{k}}{P_{k,i}^{k} + \tau_{a,i}^{k}} \tag{3.7}$$

where χ_a^{k} is a country specific EDT, because each distribution firm (corresponding to a country) is assumed to act in a different way after facing different input costs of transportation services (i.e., trade costs). Note that $\varepsilon^{k} + \chi_a^{k} = \eta_a^{k}$ (i.e., EDS + EDT = EDD) is also satisfied.

Since ε^{k} (i.e., EDS) is the same for all countries that import from country k, it should be the case that EDD is affected by the source prices, and trade costs. In particular, according to Equation 3.6, I can write:

$$\eta_a^{k} = \frac{\varepsilon^{k} \left(P_{k,i}^{k} + \tau_{a,i}^{k} \right)}{P_{k,i}^{k}} \tag{3.8}$$

This is the key expression in this paper. The validity of this relation between η_a^{k}, source prices (i.e., $P_{k,i}^{k}$), and trade costs (i.e., $\tau_{a,i}^{k}$) can be tested, and if a significant result can be found, this would support my claim that EDD is not constant across countries. Instead, an alternative elasticity of demand, which is with respect to the source price (i.e., EDS), may be a constant across countries. Hence, such a significant relation would challenge the usual definition of Armington elasticity in the literature through the equality between the elasticity of demand and the elasticity of substitution in Armington type aggregators.

4. Data

I use the United States State Export Data obtained from the TradeStats Express.[10] The data cover the years 1999 through 2007 for the exports of the US states to 230 countries around the globe. All figures are on a Free Alongside Ship value basis.[11] The series credits export merchandise to the state where the goods began their final journey to the port (or other point) of exit from the United States, as specified on official U.S. export declarations filed by shippers. Although this data set is regarded as the best available source for state export data, in the data, the origin of movement can be either the location of the factory where the export item was produced or, in many cases, the location of a distributor or a warehouse. In any case, these are exporter firms; thus, they have pricing strategies and most probably they are more experienced in the exporting process compared to the non-exporter firms. Moreover, each exporter firm, whether it is a factory or a warehouse, has distinct packaging, transportation, marketing and pricing strategies, which make their products different from each other, even though they may be exporting the very same product.[12]

I use the total value of exports from each state to the destination countries. To make the connection between the model and the empirical analysis, I take the exports of each state as a different good produced in the U.S. For instance, the exports of New York State represents a particular U.S. good, and the exports of California represents another U.S. good for the importer (i.e., the destination) country.

Table 1 - Economic Regions

African Growth and Opportunities Act (AGOA)
Andean Community (CAN)
Asia-Pacific Econ. Cooperation (APEC)
Assn. of Southeast Asian Nations (ASEAN)
Carib. Community & Common Mkt. (CARICOM)
Central American Common Market (CACM)
Central Am.-Dominician Rep. FTA (CAFTA-DR)
Commonwealth of Independent States (CIS)
European Free Trade Assn. (EFTA)
European Union
Free Trade Aggreement of the Americas (FTAA)
Gulf Cooperation Council (GCC)
North American FTA (NAFTA)
Org. of Petroleum Exporting Countries (OPEC)
South American Customs Union (SACU)
South Asian Assn. for Regional Coop. (SAARC)
Southern Cone Common Mkt. (Mercosur)

For distance measures, I calculate great circle distances between each country and each state of the U.S. by using latitudes and longitudes of capital cities of the countries and states. When testing the validity of Equation 3.8,

[10] TradeStats Express draws all state export statistics from the Origin of Movement (OM) series compiled by the Foreign Trade Division of the U.S. Census Bureau.

[11] For further information on U.S. trade data, visit http://www.census.gov/foreign-trade/guide/

[12] See Cassey (2006), Coughlin and Wall (2002), Cronovich and Gazel (1999), Hayward and Erickson (1995), and Coughlin and Mandelbaum (1991) for further discussions on the state exports data.

in order to control for trade agreement differences, I consider dummies for different economic regions that export goods from the U.S. Table 1 shows the list of economic regions that I include into my estimation process. When testing the validity of Equation 3.8, I also use GDP, GDP per capita, population, exchange rate, and purchasing power parity data obtained from World Development Indicators for the years 1999-2007.

5. Estimation Methodology

I start with estimating η_a^k (i.e., EDD) for each destination (i.e., importer) country. Then, I test the validity of having a positive relation between η_a^k and trade costs given in Equation 3.8. For robustness, I employ two different estimation methods, ordinary least squares (OLS) and Poisson Pseudo-Maximum Likelihood (PPML). In this section, I consider the conditions under which OLS and PPML can be used. For notational simplicity, I am going to remove the superscript k (representing the exporter country) from all variables, since my data set only includes exports from the U.S. to the rest of the world consisting of 230 countries.

5.1. Estimation of η_a

In order to have an accurate estimate of η_a, I estimate a difference-in-difference version of Equation 3.2. First, I take the ratio of two different goods (e.g., goods i and r) in country a imported from the U.S., as follows:

$$\begin{aligned}\frac{C_{a,i}}{C_{a,r}} &= \frac{\beta_a \gamma_k \theta_i}{\beta_a \gamma_k \theta_r} \frac{\left(\frac{P_{a,i}}{P_a}\right)^{-\eta_a}}{\left(\frac{P_{a,r}}{P_a}\right)^{-\eta_a}} \frac{C_a}{C_a} \\ &= \frac{\theta_i}{\theta_r}\left(\frac{P_{a,i}}{P_{a,r}}\right)^{-\eta_a}\end{aligned}$$

Second, I take the ratio of two different goods (e.g., goods i and r) in country b imported from the U.S., as follows:

$$\begin{aligned}\frac{C_{b,i}}{C_{b,r}} &= \frac{\beta_b \gamma_k \theta_i}{\beta_b \gamma_k \theta_r} \frac{\left(\frac{P_{b,i}}{P_b^k}\right)^{-\eta_b}}{\left(\frac{P_{b,r}}{P_b^k}\right)^{-\eta_b}} \frac{C_b}{C_b} \\ &= \frac{\theta_i}{\theta_r}\left(\frac{P_{b,i}}{P_{b,r}}\right)^{-\eta_b}\end{aligned}$$

Finally, I take the ratio of the first two ratios to obtain:

$$\begin{aligned}\left(\frac{C_{a,i}}{C_{a,r}}\right) \Big/ \left(\frac{C_{b,i}}{C_{b,r}}\right) &= \left(\frac{\theta_i}{\theta_r}\left(\frac{P_{a,i}}{P_{a,r}}\right)^{-\eta_a}\right) \Big/ \left(\frac{\theta_i}{\theta_r}\left(\frac{P_{b,i}}{P_{b,r}}\right)^{-\eta_b}\right) \\ &= \left(\frac{P_{a,i}}{P_{a,r}}\right)^{-\eta_a} \Big/ \left(\frac{P_{b,i}}{P_{b,r}}\right)^{-\eta_b} \\ &= \left(\frac{P_{k,i}+\tau_{a,i}}{P_{k,r}+\tau_{a,r}}\right)^{-\eta_a} \Big/ \left(\frac{P_{k,i}+\tau_{b,i}}{P_{k,r}+\tau_{b,r}}\right)^{-\eta_b}\end{aligned}$$

where the last equality is obtained by using the definition of trade costs in Equation 3.3. Note that all the prices that I have on the right hand side of the last line are related to the source prices in the U.S. In particular, they correspond to the source prices at different states of the U.S. in my empirical analysis. Since I work with the total exports data, and since all the source prices belong to only one country (i.e., the U.S.), it is reasonable to set these source prices equal to one to obtain the following simple expression to be estimated:

$$\left(\frac{C_{a,i}}{C_{a,r}}\right) \Big/ \left(\frac{C_{b,i}}{C_{b,r}}\right) = \left(\frac{1+\tau_{a,i}}{1+\tau_{a,r}}\right)^{-\eta_a} \Big/ \left(\frac{1+\tau_{b,i}}{1+\tau_{b,r}}\right)^{-\eta_b} \tag{5.1}$$

I estimate η_a for each country by using this expression. Setting source prices equal to one implies that the export values in dollar terms now also represent the quantity of exports.

For robustness, I consider possible measurement errors in each of the variables in Equation 5.1. I consider two different types of measurement errors: proportional and additive.

5.1.1. Proportional Measurement Errors

The version of Equation 5.1 with the proportional measurement errors is given by:

$$\left(\frac{C_{a,i}+\upsilon_{a,i}}{C_{a,r}+\upsilon_{a,r}}\right)\Big/\left(\frac{C_{b,i}+\upsilon_{b,i}}{C_{b,r}+\upsilon_{b,r}}\right)=\left(\frac{1+\tau_{a,i}+\xi_{a,i}}{1+\tau_{a,r}+\xi_{a,r}}\right)^{-\eta_a}\Big/\left(\frac{1+\tau_{b,i}+\xi_{b,i}}{1+\tau_{b,r}+\xi_{b,r}}\right)^{-\eta_b} \tag{5.2}$$

I assume that if there are realized export observations (i.e., nonzero trade observations), the measurement errors are proportional to the export value. On the other hand, in the case of zero trade observations, I assume that the measurement error is additive.[13] The intuition behind this is as follows: if there is a realized (nonzero) trade observation, the measurement error should be proportional to the observation. For instance, having the very same measurement error for both a trade of \$1 million and a trade of \$1000 is less likely than having proportional measurement errors. On the other hand, if there is no trade observation (i.e., a trade observation is equal to zero), it is more likely to have an additive measurement error instead of a proportional measurement error, which would make no difference to the value of zero.

Under these assumptions, if there are no trade observations, I can rewrite Equation 5.2 as follows:

$$\left(\frac{C_{a,i}+C_{a,i}\mu_{a,i}}{C_{a,r}+C_{a,r}\mu_{a,r}}\right)\Big/\left(\frac{C_{b,i}+C_{b,i}\mu_{b,i}}{C_{b,r}+C_{b,r}\mu_{b,r}}\right)=\left(\frac{1+\tau_{a,i}+(1+\tau_{a,i})\,\kappa_{a,i}}{1+\tau_{a,r}+(1+\tau_{a,r})\,\kappa_{a,r}}\right)^{-\eta_a}\Big/\left(\frac{1+\tau_{b,i}+(1+\tau_{b,i})\,\kappa_{b,i}}{1+\tau_{b,r}+(1+\tau_{b,r})\,\kappa_{b,r}}\right)^{-\eta_b} \tag{5.3}$$

where $C^k_{a,i}\mu^k_{a,i}=\upsilon^k_{a,i}$ and so on. If I take the log of both sides, I obtain:

$$\log\left(\frac{C_{a,i}}{C_{a,r}}\right)-\log\left(\frac{C_{b,i}}{C_{b,r}}\right)=-\eta_a\log\left(\frac{1+\tau_{a,i}}{1+\tau_{a,r}}\right)+\eta_b\log\left(\frac{1+\tau_{b,i}}{1+\tau_{b,r}}\right)+\log\left(\psi_{a,b,i,r}\right) \tag{5.4}$$

where $\psi_{a,b,i,r}=\frac{(1+\mu_{a,r})(1+\mu_{b,i})}{(1+\mu_{a,i})(1+\mu_{b,r})}\left(\frac{1+\kappa_{a,i}}{1+\kappa_{a,r}}\right)^{-\eta_a}\left(\frac{1+\kappa_{b,r}}{1+\kappa_{b,i}}\right)^{-\eta_b}$. This expression can be estimated by ordinary least squares (OLS) when $\frac{(1+\mu_{a,r})(1+\mu_{b,i})}{(1+\mu_{a,i})(1+\mu_{b,r})}=\left(\frac{1+\kappa_{a,i}}{1+\kappa_{a,r}}\right)^{\eta_a}\left(\frac{1+\kappa_{b,r}}{1+\kappa_{b,i}}\right)^{\eta_b}\xi_{a,b,i,r}$, where $\xi_{a,b,i,r}$ is a random variable statistically independent of the regressors. In such a case, $\psi_{a,b,i,r}=\xi_{a,b,i,r}$ and therefore is statistically independent of the regressors.

If there is a zero trade observation, say $C^k_{a,i}=0$, I can rewrite Equation 5.2 as follows:

$$\left(\frac{\upsilon^k_{a,i}}{C^k_{a,r}+C^k_{a,r}\mu^k_{a,r}}\right)\Big/\left(\frac{C^k_{b,i}+C^k_{b,i}\mu^k_{b,i}}{C^k_{b,r}+C^k_{b,r}\mu^k_{b,r}}\right)=\left(\frac{1+\tau^k_{a,i}+\left(1+\tau^k_{a,i}\right)\kappa^k_{a,i}}{1+\tau^k_{a,r}+\left(1+\tau^k_{a,r}\right)\kappa^k_{a,r}}\right)^{-\eta_a}\Big/\left(\frac{1+\tau^k_{b,i}+\left(1+\tau^k_{b,i}\right)\kappa^k_{b,i}}{1+\tau^k_{b,r}+\left(1+\tau^k_{b,r}\right)\kappa^k_{b,r}}\right)^{-\eta_b} \tag{5.5}$$

If I take the log of both sides, I obtain:

$$-\log\left(C_{a,r}\right)-\log\left(\frac{C_{b,i}}{C_{b,r}}\right)=-\eta_a\log\left(\frac{1+\tau_{a,i}}{1+\tau_{a,r}}\right)+\eta_b\log\left(\frac{1+\tau_{b,i}}{1+\tau_{b,r}}\right)+\log\left(\psi'_{a,b,i,r}\right) \tag{5.6}$$

where $\psi'_{a,b,i,r}=\frac{(1+\mu_{a,r})(1+\mu_{b,i})}{\upsilon^k_{a,i}(1+\mu_{b,r})}\left(\frac{1+\kappa_{a,i}}{1+\kappa_{a,r}}\right)^{-\eta_a}\left(\frac{1+\kappa_{b,r}}{1+\kappa_{b,i}}\right)^{-\eta_b}$. This expression can be estimated by ordinary least squares (OLS) when $\frac{(1+\mu_{a,r})(1+\mu_{b,i})}{\upsilon^k_{a,i}(1+\mu_{b,r})}=\left(\frac{1+\kappa_{a,i}}{1+\kappa_{a,r}}\right)^{\eta_a}\left(\frac{1+\kappa_{b,r}}{1+\kappa_{b,i}}\right)^{\eta_b}\xi_{a,b,i,r}$, where $\xi_{a,b,i,r}$ is a random variable statistically independent of the regressors. In such a case, $\psi_{a,b,i,r}=\xi_{a,b,i,r}$ and therefore is statistically independent of the regressors.

[13] Helpman et al. (2008) show that almost 50% of the observations are zero trade observations in international trade. Thus, considering those observations is essential in empirical work.

5.1.2. Additive Measurement Errors

Although OLS is consistent under the assumptions that I make (i.e., assuming that error terms are additive for zero trade observations and multiplicative for nonzero trade observations), for robustness, I also consider a unique additive error term in my analysis. In such a case, I have:

$$\left(\frac{C_{a,i}^k}{C_{a,r}^k}\right) \Big/ \left(\frac{C_{b,i}^k}{C_{b,r}^k}\right) = \left(\frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}\right)^{-\eta_a} \Big/ \left(\frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right)^{-\eta_b} + \mu_{a,b,i,r} \tag{5.7}$$

where $E\left[\mu_{r,a,b,j} \middle| \frac{\theta_a}{\theta_b}, \frac{A_a(j)}{A_b(j)}, \frac{D_{r,b}}{D_{r,a}}\right] = 0$. This can be rewritten as:

$$\left(\frac{C_{a,i}^k}{C_{a,r}^k}\right) \Big/ \left(\frac{C_{b,i}^k}{C_{b,r}^k}\right) = \left(\frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}\right)^{-\eta_a} \Big/ \left(\frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right)^{-\eta_b} \upsilon_{a,b,i,r} \tag{5.8}$$

where

$$\upsilon_{a,b,i,r} = 1 + \frac{\mu_{a,b,i,r}}{\left(\frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}\right)^{-\eta_a} \Big/ \left(\frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right)^{-\eta_b}} \tag{5.9}$$

and $E\left[\upsilon_{a,b,i,r} \middle| \frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}, \frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right] = 1$. Taking the log of both sides in Equation 5.8 results in the following log-linear expression:

$$\log\left(\frac{C_{a,i}^k}{C_{a,r}^k}\right) - \log\left(\frac{C_{b,i}^k}{C_{b,r}^k}\right) = -\eta_a \log\left(\frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}\right) + \eta_b \left(\frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right) + \log\left(\upsilon_{a,b,i,r}\right) \tag{5.10}$$

To obtain a consistent estimator of the slope parameters by OLS, I assume that $E\left[\log\left(\upsilon_{a,b,i,r}\right) \middle| \frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}, \frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right]$ does not depend on the regressors.[14] Because of Equation 5.9, this condition is met only if $\mu_{a,b,i,r}$ can be written as follows:

$$\mu_{a,b,i,r} = \left(\left(\frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}\right)^{-\eta_a} \Big/ \left(\frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right)^{-\eta_b}\right) \xi_{a,b,i,r}$$

where $\xi_{a,b,i,r}$ is a random variable statistically independent of the regressors. In such a case, $\upsilon_{a,b,i,r} = 1+\xi_{a,b,i,r}$ and therefore is statistically independent of the regressors, implying that $E\left[\log\left(\upsilon_{a,b,i,r}\right) \middle| \frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}, \frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right]$ is a constant.[15]

Until now, I have shown the conditions under which OLS can be used as an estimation method. Nevertheless, for robustness, following Santos Silva and Tenreyro (2006), I also relax the assumption of $E\left[\log\left(\upsilon_{a,b,i,r}\right) \middle| \frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}, \frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right]$ not depending on the regressors, by considering the Poisson Pseudo-Maximum Likelihood (PPML) estimator. As Santos Silva and Tenreyro (2006), and Henderson and Millimet (2008) suggest, under heteroskedasticity, the parameters of log-linearized models estimated by OLS may lead to biased estimates; thus, PPML should be used. To show this, Equation 5.8 can be written as follows:

$$\left(\frac{C_{a,i}^k}{C_{a,r}^k}\right) \Big/ \left(\frac{C_{b,i}^k}{C_{b,r}^k}\right) = \exp\left(-\eta_a \log\left(\frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}\right) + \eta_b \log\left(\frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right)\right) \upsilon_{a,b,i,r} \tag{5.11}$$

Assuming $E\left[\upsilon_{a,b,i,r} \middle| \frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}, \frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right] = 1$, then Equation 5.11 may be estimated consistently using the PPML estimator.

In sum, I consider two different estimation methods in the estimation of Equation 5.1: OLS and PPML.

[14] It is well known that modeling zero interregional flows using a normal error process leads to problems. If the dependent variable cannot take a value below zero, then a normal error process is a poor approximation. Nevertheless, I don't have such a concern, because the log-linearized equation does have values below zero, by considering the (log) ratio of export values.

[15] Under the assumption of a unique additive measurment error, the issue of zero trade observations can be handled by setting zero trade observations equal to one. I need this assumption mostly because the log of zero and a division by zero are both unidentified.

5.2. Estimation of the Relation between η_a and Trade Costs

As above, it is reasonable to set these source prices equal to one to obtain the following simple expression to be estimated:

$$\eta_a = \varepsilon (1 + \tau_{a,i}) \tag{5.12}$$

By using the very same methodology that I use to estimate Equation 5.1, I estimate Equation 5.12. For robustness, I again consider two different types of measurement errors: proportional and additive.[16]

5.2.1. Proportional Measurement Errors

In particular, if the measurement errors (of trade costs) are multiplicative, I can rewrite Equation 5.12 as follows:

$$\eta_a (1 + \upsilon_a) = \varepsilon (1 + \tau_{a,i}) \left(1 + \xi_{a,i}\right)$$

If I take the log of both sides, I obtain:

$$\log \eta_a = \log (\varepsilon) + \log (1 + \tau_{a,i}) + \log \psi_{a,i}$$

where $\psi_{a,i} = \frac{\left(1+\xi_{a,i}\right)}{(1+\upsilon_a)}$ is assumed to be independent and to have a mean of zero to be estimated by OLS.

5.2.2. Additive Measurement Errors

Alternatively, if there is a unique additive error term, I can rewrite Equation 5.12 as follows:

$$\eta_a = \varepsilon (1 + \tau_{a,i}) + \mu_{a,i}$$

This can be rewritten as:

$$\eta_a = \varepsilon (1 + \tau_{a,i}) \upsilon_{a,i} \tag{5.13}$$

where

$$\upsilon_{a,i} = 1 + \frac{\mu_{a,i}}{\varepsilon (1 + \tau_{a,i})} \tag{5.14}$$

and $E\left[\upsilon_{a,i} \left|(1 + \tau_{a,i})\right.\right] = 1$. Taking the log of both sides in Equation 5.13 results in the following log-linear expression:

$$\log \eta_a = \log (\varepsilon) + \log (1 + \tau_{a,i}) + \log \upsilon_{a,i} \tag{5.15}$$

To obtain a consistent estimator of the slope parameters by OLS, I assume that $E\left[\log (\upsilon_{a,i}) \left|(1 + \tau_{a,i})\right.\right]$ does not depend on the regressors. Because of Equation 5.14, this condition is met only if $\mu_{a,i}$ can be written as follows:

$$\mu_{a,i} = \varepsilon (1 + \tau_{a,i}) \xi_{a,i}$$

where $\xi_{a,i}$ is a random variable statistically independent of the regressors. In such a case, $\upsilon_{a,i} = 1 + \xi_{a,i}$ and therefore is statistically independent of the regressors, implying that $E\left[\log (\upsilon_{a,i}) \left|(1 + \tau_{a,i})\right.\right]$ is a constant.

I also relax the assumption of $E\left[\log (\upsilon_{a,i}) \left|(1 + \tau_{a,i})\right.\right]$ not depending on the regressors, by considering the PPML estimator. To show this, Equation 5.13 can be written as follows:

$$\eta_a = \exp \left(\log (\varepsilon) + \log (1 + \tau_{a,i})\right) \upsilon_{a,i} \tag{5.16}$$

Assuming $E\left[\log (\upsilon_{a,i}) \left|(1 + \tau_{a,i})\right.\right] = 1$, then Equation 5.11 may be estimated consistently using the PPML estimator.

In sum, I again consider two different estimation methods in order to test the validity of Equation 5.12: OLS and PPML.

[16] Because of my methodology for zero trade observations in the estimation of η's, there is no zero observation issue in this second estimation.

5.3. Trade Costs

Before I proceed, I have to clarify the connection between the model and the empirical analysis in terms of trade costs. Anderson and van Wincoop (2004) categorize the trade costs under two names, costs imposed by policy (tariffs, quotas, etc.) and costs imposed by the environment (transportation, wholesale and retail distribution, insurance against various hazards, etc.). In this context, I define trade costs as follows:

$$1+\tau_{a,i}=\underbrace{(D_{a,i})}_{\text{freight}}\times\underbrace{(1+t_a)}_{\text{other}}\times\underbrace{(1+w_a)}_{\text{distribution}}$$

where $D_{a,i}$ is the distance between country a and state i of the U.S. to capture the freight costs; t_a is representing the (net) costs related to tariffs (and quotas) from the U.S. to country a; and w_a is the (net) costs related to the local wholesale and retail distributions, and insurance in country a.

After this definition, I can now introduce the final version of Equation 5.1 to be estimated:

$$\begin{aligned}\left(\frac{C_{a,i}}{C_{a,r}}\right)\Big/\left(\frac{C_{b,i}}{C_{b,r}}\right) &= \left(\frac{(D_{a,i})(1+t_a)(1+w_a)}{(D_{a,r})(1+t_a)(1+w_a)}\right)^{-\eta_a}\Big/\left(\frac{(D_{b,i})(1+t_b)(1+w_b)}{(D_{b,r})(1+t_b)(1+w_b)}\right)^{-\eta_b} \\ &= \left(\frac{D_{a,i}}{D_{a,r}}\right)^{-\eta_a}\Big/\left(\frac{D_{b,i}}{D_{b,r}}\right)^{-\eta_b} \qquad (5.17)\end{aligned}$$

where η values for each country can be estimated. In terms of the estimation strategy, after taking average of trade (i.e., export) ratios over time (between 1999 and 2007), since all the variables and parameters depend on either a or b, I can estimate this equation for each (a,b) country pair separately. Hence, I run a separate regression for each possible (a,b) pair and select the estimates coming out of regressions with the highest explanatory powers. For instance, in order to have an estimate of η_a for country a, I consider all possible trade ratios that include country a. Then, among those estimated regressions, I select the one with the highest explanatory power (in terms of R-bar sqd.). The corresponding η_a is the one obtained from that regression with the highest explanatory power.

After having measures of η_a's, I continue with testing for a relation between η_a and trade costs. In particular, the final version of Equation 5.12 to be estimated can be written as follows:

$$\eta_a=\varepsilon\,(D_{a,i})\,(1+t_a)\,(1+w_a) \qquad (5.18)$$

where I use economic region specific dummies for $\varepsilon\,(1+t_a)\,(1+w_a)$'s. Using these dummies can also be thought as a part of the robustness analysis to let ε's be region specific variables. In such a case, the trade costs other than the freight costs are mostly controlled in the estimation, however neither ε nor $(1+t_a)\,(1+w_a)$'s can be identified due to the dummy variable trap. Although having very similar (mostly the same) $(1+t_a)$ values are reasonable within the same economic region, one may think that the countries in the same economic region may not share the same ε's and/or the same distribution costs, $(1+w_a)$'s. In such a case, $\varepsilon_a\,(1+w_a)$ can be thought as a part of the error term (i.e., the unobserved term) in the estimation process where ε_a is the country specific EDS. As an alternative, the local distribution costs can also be related to the wage rates of the importer countries, where wage rates can be proxied by income, income per capita, or purchasing power parity.[17] Since imports of a country is positively related to its income, the volume of imports may also be an indicator for high local markups (i.e., high local distribution costs). Hence, variables such as income, income per capita, purchasing power parity, and imports can also be included into the regression analysis for robustness.

It is worth noting that the trade costs can also be defined as $1+\tau_{a,i}=(D_{a,i})^{\delta}\,(1+t_a)\times(1+w_a)$ where δ represents the elasticity of distance. I such a case, my estimated equation would change as $\delta\eta\,(a)=\delta\varepsilon\,(D_{a,i})^{\delta}\,(1+t_a)\,(1+w_a)$, where $\delta\eta\,(a)$ would be the estimate obtained from Equation 5.17. This change would only affect the magnitude of

[17] See Alessandria and Kaboski (2004) who links larger markups in high income importer's to consumer's opportunity cost of search. Also see Crucini and Yilmazkuday (2008) who show the local distribution costs are directly related to the wage rates in the distribution sector.

region specific dummies and the definition of the coefficient in front of the distance measures, but it would have no effect on the main purpose of the empirical analysis. Nevertheless, for robustness, I will test for this possibility by testing a restriction in which $\delta = 1$.

5.4. Source Prices

Up to now, I have set the source prices equal to 1 for empirical convenience. This simplicity would have almost no effect on the estimation of Equation 5.1, since the ratio of two source prices is considered there.[18] However, I may loose some important information by doing so when I estimate $\eta_a = \frac{\varepsilon(P_{k,i}+\tau_{a,i})}{P_{k,i}}$ where the numerator includes the destination prices while the denominator includes the source prices. In basic terms, it can be shown easily that η_a decreases in $P_{k,i}$. Thus, anything that affects the source prices also affects η_a. In a special case under which there is a price discrimination, if the exporter firms at the source have increasing returns to scale, or if they want to have a market access to an importer country (to increase future profits) through lower prices, the following are implied:

- Source prices may decrease (i.e., η_a may increase) with increasing imports of the importer countries.
- Since increasing exports can be achieved by increasing incomes of the importer countries, source prices may also decrease (i.e., η_a may increase) with increasing sizes of the importer countries (which can be proxied by income or population levels).
- If the level of prices or the standard of living is low in an importer country, the exporter firm may want to reduce its prices further in order to have a market access to this country. In such a case, the lower the prices (which can be proxied by the exchange rate) or the lower the standard of living (which can be proxied by the purchasing power parity), the lower are the source prices (i.e., the higher is η_a).

Although I use economic region specific dummies while testing the relation in Equation 5.18, they may not capture all the country specific variation in η_a due to the pricing strategies mentioned above. Hence, consistent with what I suggested related to controlling for the local distribution costs in the importer country (i.e., including income, income per capita, purchasing power parity, and imports into the regression analysis), additional variables such as exports, income, population, exchange rate, and purchasing power parity can be included in the estimation of Equation 5.18 for robustness.

6. Empirical Results

The results for the estimation of η_a are given in Table 2.

Table 2 - Estimation of η_a

	First Quartile	Median	Third Quartile
η_a (OLS)	3.11	7.04	20.57
R-bar sqd. (OLS)	0.36	0.46	0.57
η_a (PPML)	10.71	27.34	41.12
R-bar sqd. (PPML)	1.00	1.00	1.00

[18] According to Equation 5.1, actually, the ratio of the destination prices are considered. However, after controlling for the ratio of trade costs, the ratio of the destination prices approximately reduce to the ratio of source prices.

As is evident, while the median OLS estimate of η_a is 7.04, the median PPML estimate of η_a is 27.34. The median R-bar sqd. value for OLS is 0.47 while the median R-bar sqd. value for PPML is 1.00.[19] Although the median OLS estimate of η_a (i.e., 7.04) is close to the estimates in the literature, the median PPML estimate of η_a (i.e., 27.34) is higher than the ones in the literature. In particular, Hummel's (2001) estimates range between 4.79 and 8.26; the estimates of Head and Ries (2001) range between 7.9 and 11.4; the estimate of Baier and Bergstrand (2001) is about 6.4; Harrigan's (1996) estimates range from 5 to 10; Feenstra's (1994) estimates range from 3 to 8.4; the estimate by Eaton and Kortum (2002) is about 9.28; the estimates by Romalis (2007) range between 6.2 and 10.9; the (mean) estimates of Broda and Weinstein (2006) range between 4 and 17.3. The main source of this difference may be using different data sets. In particular, while these studies in the literature mostly measure the elasticity of substitution for different goods, this paper measures the elasticity of substitution for different U.S. states. Nevertheless, this doesn't affect the main result of this paper.

Table 3 - Trade Costs, Source Prices, and η_a by OLS

	Dependent Variable: $\log(\eta_a)$												
Dist	0.18							1.10	1.11	0.93	0.91	0.87	0.86
	(0.01)							(0.13)	(0.12)	(0.12)	(0.11)	(0.14)	(0.13)
Impo		0.16						3.48	3.66				
		(0.01)						(0.73)	(0.69)				
GDP			0.06							0.20	0.21		
			(0.01)							(0.07)	(0.07)		
GDPP				0.15								0.20	0.24
				(0.01)								(0.06)	(0.05)
XR					0.45			0.08		0.04		0.04	
					(0.05)			(0.04)		(0.04)		(0.05)	
PPP						0.52			0.18		0.15		0.16
						(0.05)			(0.03)		(0.03)		(0.02)
Dum	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-bar.	0.09	0.01	0.01	0.01	0.01	0.01	0.43	0.67	0.74	0.64	0.70	0.62	0.68

Notes: The estimation is by OLS. The standard errors are in parenthesis. The sample size for all estimations is 266 after repeating the observations of the countries belonging to more than one economic regions because of the economic region specific dummies. Dist stands for log distance, Impo for log imports, GDP for log GDP, GDPP for log GDP per capita, XR for log exchange rate, PPP for log purchasing power parity, Dum for economic region specific dummies, and R-bar for R-bar sqd.

[19] Note that the R-bar sqd. values for OLS and PPML don't correspond to the R-bar sqd. values of the particular η_a estimates given in the table. They are the first quartile, median, and the third quartile of the R-bar sqd. distribution.

By using the estimated η_a measures, I estimate the relation between η_a, trade costs, and source prices. The OLS estimation results obtained by using the OLS estimates of η_a are given in Table 3, and the PPML estimation results obtained by using the PPML estimates of η_a are given in Table 4.

Table 4 - Trade Costs, Source Prices, and η_a by PPML

	Dependent Variable: $\log(\eta_a)$												
Dist	0.23							1.22	1.24	0.96	0.97	0.92	0.97
	(0.01)							(0.18)	(0.19)	(0.16)	(0.16)	(0.15)	(0.16)
Impo		0.21						4.17	3.97				
		(0.01)						(0.97)	(0.91)				
GDP			0.07							0.20	0.18		
			(0.01)							(0.05)	(0.05)		
GDPP				0.19								0.25	0.25
				(0.01)								(0.06)	(0.06)
XR					0.41			0.10		0.06		0.10	
					(0.05)			(0.03)		(0.02)		(0.03)	
PPP						0.45			0.13		0.09		0.13
						(0.05)			(0.03)		(0.02)		(0.03)
Dum	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-bar.	0.51	0.45	0.34	0.38	0.46	0.49	0.78	0.93	0.94	0.92	0.93	0.95	0.96

Notes: The estimation is by PPML. The standard errors are in parenthesis. The sample size for all estimations is 266 after repeating the observations of the countries belonging to more than one economic regions because of the economic region specific dummies. Dist stands for log distance, Impo for log imports, GDP for log GDP, GDPP for log GDP per capita, XR for log exchange rate, PPP for log purchasing power parity, Dum for economic region specific dummies, and R-bar for R-bar sqd.

In all regressions, I include only uncorrelated variables to avoid any multicollinearity problem. For instance, GDP, GDP per capita, and imports, or the exchange rates and purchasing power parities can also be correlated with each other. As is evident, all the estimates are highly significant in all of the estimations which supports that EDD, η_a, is not constant across countries. In particular, EDD increases in trade costs and decreases in the source prices. Hence, my empirical results in fact challenge the definition of constant elasticity of substitution in the literature. It is more plausible that EDS may be constant across countries. The highest explanatory power (i.e., a R-bar sqd.

of 0.74) in OLS regressions is achieved when (log) distance, (log) imports, and (log) purchasing power parity are included into the regression. In such a case, a one percent increase in distance leads to around 1.1 percent increase in the elasticity, a one percent increase in imports leads to around 3.7 percent increase, and a one percent increase in purchasing power parity leads to around 0.2 percent increase.

The highest explanatory power (i.e., a R-bar sqd. of 0.96) in PPML regressions is achieved when (log) distance, (log) GDP per capita, and (log) purchasing power parity are included into the regression. In such a case, a one percent increase in distance leads to around 1 percent increase in the elasticity, a one percent increase in GDP per capita leads to around 0.3 percent increase, and a one percent increase in purchasing power parity leads to around 0.1 percent increase.

The results in Table 3 and Table 4 are also robust to the selection of different measures used. For instance, using log GDP, log GDP per capita, or log imports, all result in very similar explanatory powers, although their magnitudes are, of course, different in numerical terms. Similarly, using exchange rate or purchasing power parity also result in very similar explanatory powers, this time with very similar numerical magnitudes. Overall, if I want to make a summary of both tables, I can say that, on average, a one percent increase in distance leads to around 1 percent increase in the elasticity, a one percent increase in income leads to around 0.2 percent increase, a one percent increase in imports leads to around 4 percent increase, a one percent increase in exchange rate leads to around 0.1 percent increase, and a one percent increase in purchasing power parity leads to around 0.1 percent increase. These results are all supported by high explanatory powers.

Finally, in both estimation methods, the restriction of having a coefficient of one for log distance measures are tested, and the null hypotheses of valid restrictions are accepted. In other words, the (log) distance measure may in fact enter the regression analyses with a coefficient of one.

Comparison with Hummels and Lugovskyy (2008)

I compare my empirical results with the results of Hummels and Lugovskyy (2008; HL henceforth) in terms of varying Armington elasticities from one importer country to another. HL theoretically show that the Armington elasticity increases in population density and decreases in GDP per capita. Besides testing this relation coming from their model in a log-linear form, they also test an implied relation that the elasticity is higher in large markets (proxied by log GDP), and lower in rich markets (proxied by log GDP per capita), conditional on market size. In sum, they have two key relations in order to show how elasticities differ between importer countries. In terms of this paper's notation, HL have the following relations:

$$\eta_a = f\left(\log\left(GDP\right), \log\left(GDPP\right)\right)$$

and

$$\log\left(\eta_a\right) = f\left(\log\left(POP\right), \log\left(GDPP\right)\right)$$

where $GDPP$ denotes GDP per capita, and POP denotes population. Notice that the first regression is a semi-log relationship, and the second one is log-linear. I already mentioned about the possible issues related to their log-linear estimation approach in the introduction, so I won't repeat myself here. Instead, I will compare the explanatory power of my method with theirs by using my data.

If I replicate the regression analysis of HL by using my data, I obtain the results given in Table 5. While the first two columns of Table 5 show the results of HL for comparison, the other columns show my results. As is evident in the first column, HL show that elasticities increase with GDP and decrease with GDP per capita, where R^2 is 0.17. Alternatively, according to the second column, HL show that elasticities decrease with GDP per capita and increase with population, where R^2 is not depicted. Although the HL estimates are significant and have their expected signs, the explanatory power of their OLS estimation is too low compared to my results in Table 3. When I replicate their method by using my data (i.e., by including both GDP and GDP per capita into the regression), I first obtain the results in column 3, where the signs of the estimates are as expected from the theory of HL, but they are not significant when estimated by OLS; the R-bar sqd. is also low in column 3. Column 4 shows that no estimation can be made by PPML when both GDP and GDP per capita are included into the regression, most probably due to a multicollinearity problem. When I replicate the alternative regression of HL by using my data (i.e., by including GDP per capita and population into the regression), I obtain the results given in columns 5 and 6. In column 5, where OLS is used, my results are consistent with HL in terms of having significant effects and the expected signs of the estimates. However, the R-bar sqd. value is still too low compared to my OLS results in Table 3. When I continue with the PPML estimation in column 6, I obtain a high R-bar sqd. value, but this time the signs of the estimates are not as expected from the theory of HL. And, compared to my explanatory powers in Table 4, this regression has a lower power.

Table 5 - Comparison with HL

	Dependent Variable							
	η_a	$\log(\eta_a)$	η_a	η_a	$\log(\eta_a)$	$\log(\eta_a)$	$\log(\eta_a)$	$\log(\eta_a)$
	HL (OLS)	HL (OLS)	OLS	PPML	OLS	PPML	OLS	PPML
GDP	0.057		1.187	?			0.172	-0.255
	(0.001)		(1.202)	?			(0.112)	(0.030)
GDPP	-0.101	-0.050	-3.212	?	-0.164	0.155	-0.340	-0.012
	(0.003)	(0.003)	(0.817)	?	(0.056)	(0.016)	(0.090)	(0.023)
POP		0.076			0.175	0.105		
		(0.001)			(0.031)	(0.009)		
R-bar	0.17	?	0.18	?	0.16	0.71	0.14	0.79

Notes: The standard errors are in parenthesis. The sample size for all estimations is 266 after repeating the observations of the countries belonging to more than one economic regions because of the economic region specific dummies. GDP stands for log GDP, GDPP for log GDP per capita, POP for log population, and R-bar for R-bar sqd.

Finally, although it is not suggested by HL, for robustness, I run an alternative regression in the following form:

$$\log(\eta_a) = f(\log(GDP), \log(GDPP))$$

This regression is consistent with the predictions of HL in the sense that the elasticities increase in GDP and decrease in GDP per capita. The results that I obtain by using my data are depicted in columns 7 and 8 in Table 5. As is evident in column 7, the OLS results are almost significant and the expected signs of the estimates are achieved. However, compared to Table 3, the explanatory power is still too low. When I move to column 8, which is the estimation by PPML, both GDP and GDP per capita has negative signs, which is against the expectations of HL. Although the explanatory power is high, it is still lower than my results in Table 4.

In sum, my data cannot be explained enough by using the method of HL. Instead, if I compare Table 5 with Table 3 and Table 4, I see that my method provides much more explanation compared to the method of HL. My alternative regressions for robustness support this result.

7. Conclusions

I attempted to analyze whether or not the elasticity of substitution across goods changes from one importer country to another one in the context of Armington aggregators in international trade. Under the assumption of large number of varieties, the Armington aggregators have the property that the elasticity of substitution across goods is equal to the price elasticity of demand. Hence, any change in the price elasticity of demand corresponds to a change in the elasticity of substitution across goods. In this context, first, for any type of demand function, I showed, under additive trade costs, that the elasticity of demand with respect to the destination price (EDD) can be decomposed into two parts: the elasticity of demand with respect to the source price (EDS) and the elasticity of demand with respect to the trade costs (EDT). It is implied that EDD is an increasing function of EDS and trade costs, and it is decreasing in the source prices. The empirical analysis supports this relation by showing that EDD in fact increases with trade costs and decreases with the source prices. This means that while it is more likely for EDS to be constant across countries, EDD is not constant (which implies that EDT is not constant either), and it changes from one importer to another. Overall, this paper challenges mostly the CES type aggregators that are commonly used in the trade literature by showing that the Armington elasticity is not constant across importer countries; instead, it increases with trade costs and decreases with the source prices.

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