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Yilmazkuday, Hakan

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Hakan Yilmazkuday†

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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 under the assumption of a large number of varieties, systematically changes from one importer country to another 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 elasticity of demand with respect to the destination price is equal to the sum of the elasticity of demand with respect to the source price and the elasticity of demand with respect to the trade costs. The empirical results using the United States export data at the state level support this relation; hence, it is more likely to have a constant elasticity of demand with respect to the source price rather than a constant Armington elasticity under additive trade costs. In terms of policy implications, the constant Armington elasticity undervalues the effects of a policy change around 3 or 4 times compared to the importer-specific Armington elasticities.

JEL Classification: F12, F13, F14

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

1. Introduction

Many trade models have in common a 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) among 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.

Especially in the context of the static applied general equilibrium trade literature, McDaniel and Balistreri (2002) provide a key insight: the Armington elasticity is a key parameter that is used by policymakers to derive quantitative results, because the effects of an international trade policy change are evaluated by the conversion of policy changes into price effects. These price effects (i.e., price changes) are the key in determining the effects of trade policies on the real macroeconomic variables such as output, employment, trade flows, and economic welfare, as well as other important variables of interest. In terms of modeling, the connection between the price changes

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†Department of Economics, Temple University, Philadelphia, PA 19122, USA; Tel: +1-215-204-8880; Fax: +1-215-204-8173; e-mail: skuday@gmail.com

and the real macroeconomic variables is usually achieved by employing the Armington elasticity (e.g., the effects of changes in tariffs and taxes on the real variables are evaluated through this elasticity). Therefore, there is no question that the measurement of the Armington elasticity is of fundamental importance in determining the response of trade models to policy experiments. But, is this critical parameter really *constant*?

This paper investigates whether the Armington elasticity systematically changes from one importer country to another in the context of international trade. For instance, when exports of the U.S. states to the rest of the world are considered, the Armington elasticity corresponds to the CES among 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 usual assumption of monopolistic competition 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.

Under additive trade costs, this paper shows that the price **e**lasticity of **d**emand with respect to the **d**estination price (EDD) can be decomposed into two parts for any type of demand function: 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). It is also shown that EDD is the sum of EDS and EDT. Furthermore, this paper depicts that EDD is increasing in EDS and trade costs, while it is decreasing in source prices. In order to test the relation among EDD, EDS, trade costs, and source prices, 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 are used. The empirical analyses support the view that EDD increases with trade costs and decreases with source prices. This result suggests 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; this is opposed to the CES assumption that is commonly used in the trade literature.

The intuition for this result is as follows: It is known that an importer's demand for an exporter's good depends on both the source price and the trade costs. However, the formation of elasticity is the key here. For instance, given that an importer is going to import from a particular source, as in the spatial pricing theory, the importer may form her elasticity as she is at the source, although her demand still depends on trade costs.[1] In other words, given that an importer is going to shop at a particular source, preferences should be defined over the source prices, which captures the extent to which individuals are willing to substitute between different varieties. In such a case, different importers shopping at the same source may share the same EDS. This is the case when importers shop in an 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 the importers 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 in the market (e.g., the shopping centers). Given that an individual is going to shop at a particular store, the additional trade costs related to going to the store (e.g., depreciation of cars, gas prices, auto insurance costs, driving risks) are only additional costs that have to be paid by the individual. In this context, given that an individual is going to shop at a particular store, she only compares the source prices; thus, the elasticity measure should be formed with respect to the source prices at the store. When this story is generalized to the context of U.S. exports at the state level where there is an elasticity of substitution between the products of different states, given that 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 in different states.

In terms of modeling, a partial equilibrium trade model is introduced where each country has a distinct import demand for different countries' goods (represented by a sub-utility). For instance, the United Kingdom (U.K.) has

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

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 (each produced in a different state) imported from the U.S. For the Armington aggregator, it is verified that EDD is the sum of EDS and EDT, and that EDD is increasing in EDS and trade costs. 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 Armington elasticity is not constant (i.e., uncommon) across importer countries.

The results of this paper also correspond to important policy implications: individual responses, rather than an imposed average response, of the importers should be taken into account, because each importer has its own demand characteristics. In particular, at the U.S. level, it is empirically shown that the constant Armington elasticity undervalues the effects of a policy change around 3 or 4 times compared to the importer-specific Armington elasticities.

Related Literature

This subsection briefly describes 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 a 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 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 country of origin of the 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 referring to 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 has 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. It is not only shown that the Armington elasticity is variable across these 230 countries, but also shown

[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,

that the difference in terms of elasticities can be explained by the source prices and trade costs. For instance, 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 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 (2009; 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 is open to improvement 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 the data of this paper 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) has been criticized by Santos Silva and Tenreyro (2006), and Henderson and Millimet (2008) who suggest that, under heteroskedasticity, the parameters of log-linearized models estimated by OLS may lead to biased estimates; thus, an alternative estimation method, Poisson Pseudo-Maximum Likelihood (PPML), should be preferred. This 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 the empirical analysis of HL is replicated by using the data of this paper (i.e., by running a regression including importer GDP and importer GDP per capita), it is found that the R^2 value is around 0.18, which is very close to what HL have. Fortunately, the approach used in this paper allows 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, correlated variables (e.g., import volumes and income levels) are not included into the regression at the same time. The regression analyses of this paper 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 introduces a simple trade model. Section 3 describes the data. Section 4 provides insights and depicts the estimation methodology. Section 5 gives the empirical results. Section 6 discusses the policy implications. Section 7 concludes. The Appendix depicts the connection among EDD, EDS, and EDT for a general type demand function.

2. The Model

The economy consists of a finite number of countries. Each country may import goods from all any number of other countries. In the model, generally speaking, $H^c_{a,b}$ stands for the variable H, where a is the importer country (i.e.,

[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.

the destination), b is the good, and c is the exporter country (i.e., the source).

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

$$C_a^k \equiv \left(\sum_i \left(\varphi_{a,i}^k\right)^{\frac{1}{\eta_a^k}} \left(C_{a,i}^k\right)^{\frac{\eta_a^k-1}{\eta_a^k}}\right)^{\frac{\eta_a^k}{\eta_a^k-1}} \tag{2.1}$$

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; $\varphi_{a,i}^k$ is a destination, source, and good specific taste parameter which can be decomposed as $\varphi_{a,i}^k = \beta_a \gamma_k \theta_i$ where 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.[8] 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 condition for expenditure on good i, imported by country a, from country k, is:

$$C_{a,i}^k = \varphi_{a,i}^k \left(\frac{P_{a,i}^k}{P_a^k}\right)^{-\eta_a^k} C_a^k \tag{2.2}$$

where $P_{a,i}^k = P_{k,i}^k + \tau_{a,i}^k$ is the price of good i imported by country a, from the source country, k, $P_{k,i}^k$ is the price of good i in country k (i.e., the source), $\tau_{a,i}^k > 0$ is a good specific net additive transportation cost from country k to country a, and $P_a^k \equiv \left(\sum_i \varphi_{a,i}^k \left(P_{a,i}^k\right)^{1-\eta_a^k}\right)^{\frac{1}{1-\eta_a^k}}$ is the price index of the goods in country a exported from country k. It is implied that $P_a^k C_a^k = \sum_i P_{a,i}^k C_{a,i}^k$.

Elasticity of Substitution

Under the assumption of a large number of varieties (i.e., the usual assumption that the budget share of good i is zero, which implies that the individual variety prices have zero effects on the aggregated price index of all varieties), the elasticity of demand for the imported good with respect to the destination price (i.e., EDD) is given by η_a^k. However, the elasticity of demand for the imported good with respect to the source price (i.e., EDS) is not constant, it depends on the source price, the EDD, and the trade cost, as follows:

$$\varepsilon_a^k = \frac{P_{k,i}^k \eta_a^k}{P_{k,i}^k + \tau_{a,i}^k} \tag{2.3}$$

where ε_a^k is an importer specific EDS. Note that, in a special case in which trade costs are equal to zero, $\varepsilon_a^k = \eta_a^k$.

Similarly, the elasticity of demand for the imported good with respect to the trade costs (i.e., EDT) is can be calculated as:

$$\chi_a^k = \frac{\tau_{a,i}^k \eta_a^k}{P_{k,i}^k + \tau_{a,i}^k} \tag{2.4}$$

where χ_a^k is an importer specific EDT.

Combination of Equations 2.3 and 2.4 imply that:

$$\varepsilon_a^k + \chi_a^k = \eta_a^k$$

which means that the elasticity of demand with respect to the destination price is equal to the sum of the elasticity of demand with respect to the source price and the elasticity of demand with respect to the trade costs (i.e., EDS

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

+ EDT = EDD). The Appendix shows that this relation holds for any type of demand function, not just the CES formulation.

According to Equation 2.3,

$$\eta_a^k = \frac{\varepsilon_a^k \left(P_{k,i}^k + \tau_{a,i}^k\right)}{P_{k,i}^k} \tag{2.5}$$

η_a^k (i.e., EDD) increases in ε_a^k (i.e., EDS) and trade costs, and it decreases in the source prices, *ceteris paribus*.

There a couple of possibilities. One of them is that η_a^k is constant (i.e., common) and ε_a^k is variable (i.e., uncommon) across importer countries; this would imply that the Armington elasticities are constant (i.e., common) across importer countries. However, as will be shown below, the data don't support this possibility. Another possibility is that ε_a^k is constant (i.e., common) and η_a^k is variable (i.e., uncommon) across importer countries; this would imply that the Armington elasticities increase in the trade costs and decreases in source prices. As will be shown below, the data support this second possibility.[9] Hence, it is more likely to have a constant (i.e., common) ε_a^k and a variable (i.e., uncommon) η_a^k across importer countries.

Equation 2.5 is the key expression in this paper. The validity of the 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 the claim that η_a^k is not constant across importers. Instead, an alternative elasticity of demand, which is with respect to the source price (i.e., ε_a^k), may be a constant across countries. Hence, such a significant relation would challenge the usual definition of the Armington elasticity in the literature through the equality between the elasticity of demand and the elasticity of substitution in Armington type aggregators, under the assumption of a large number of varieties.

3. Data

The main source of trade data is 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]

The total values of exports from each state to the destination countries are used. To make the connection between the model and the empirical analysis, the exports of each state are considered as a different good produced in the U.S., which are connected to each other through the Armington elasticity. For instance, the exports of New York State represent a particular U.S. good, and the exports of California represent another U.S. good for the importer (i.e., the destination) country.

When testing the validity of Equation 2.5, in order to control for trade agreement differences, dummies for different economic regions that export goods from the U.S. are used. Table 1 shows the list of economic regions that are included into the estimation process. When testing the validity of Equation 2.5, Gross Domestic Product (GDP),

[9] Nevertheless, there is an obvious third possibility in which both η_a^k and ε_a^k are variable across importers. This particular possibility is also considered in the estimation procedure, below.

[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.

GDP per capita, population, exchange rate, and purchasing power parity data obtained from World Development Indicators for the years 1999-2007 are also used. Finally, for distance measures, great circle distances between each country and each state of the U.S. are calculated by using latitudes and longitudes of capital cities of the countries and states.

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)

4. Estimation Methodology

The first step is to estimate η_a^k (i.e., EDD) for each destination (i.e., importer) country. Then, the validity of having a positive relation between η_a^k and trade costs given in Equation 2.5 is tested. For robustness, two different estimation methods are employed, ordinary least squares (OLS) and Poisson Pseudo-Maximum Likelihood (PPML). In this section, the conditions under which OLS and PPML can be used are considered.

4.1. Estimation of η_a^k

In order to have an accurate estimate of η_a^k, a difference-in-difference version of Equation 2.2 is estimated. As will be shown in more details below, employing a difference-in-difference approach effectively eliminates the distribution margin and the tariffs (or the quotas) from the theoretical trade equation, which makes the estimation results robust to these issues. First, the ratio of two different goods (e.g., goods i and r) in country a imported from country k

(i.e., the U.S.) is taken as follows:

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

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

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

Finally, the ratio of the first two ratios is taken to obtain:

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

where the last equality is obtained by using the definition of trade costs, $P_{a,i}^k = P_{k,i}^k + \tau_{a,i}^k$. Note that all the prices 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 the empirical analysis. Since the total exports data are considered, 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:

$$
\left(\frac{C_{a,i}^k}{C_{a,r}^k}\right) \Big/ \left(\frac{C_{b,i}^k}{C_{b,r}^k}\right) = \left(\frac{1 + \tau_{a,i}^k}{1 + \tau_{a,r}^k}\right)^{-\eta_a^k} \Big/ \left(\frac{1 + \tau_{b,i}^k}{1 + \tau_{b,r}^k}\right)^{-\eta_b^k} \tag{4.1}
$$

For each country, η_a^k is estimated 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. Although setting source prices equal to one may seem as a strong assumption from a conservative researcher's point of view, this is one of the best feasible approaches considering its empirical convenience that will be clearer below. The best approach should calculate source prices at each state; however, because the data represent the total exports rather than a disaggregated level exports (e.g., good level exports), it is not feasible to calculate or estimate source prices which are comparable across states from the available data. Nevertheless, this strong assumption will be relaxed, and its implications will be discussed further below.

For robustness, possible measurement errors in each of the variables in Equation 4.1 are considered. Two different types of measurement errors are taken into account: proportional and additive.

4.1.1. Proportional Measurement Errors

The version of Equation 4.1 with the proportional measurement errors is given by:

$$\left(\frac{C^k_{a,i}+\upsilon^k_{a,i}}{C^k_{a,r}+\upsilon^k_{a,r}}\right)\Bigg/\left(\frac{C^k_{b,i}+\upsilon^k_{b,i}}{C^k_{b,r}+\upsilon^k_{b,r}}\right)=\left(\frac{1+\tau^k_{a,i}+\xi^k_{a,i}}{1+\tau^k_{a,r}+\xi^k_{a,r}}\right)^{-\eta^k_a}\Bigg/\left(\frac{1+\tau^k_{b,i}+\xi^k_{b,i}}{1+\tau^k_{b,r}+\xi^k_{b,r}}\right)^{-\eta^k_b} \tag{4.2}$$

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, 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 zero trade observations, Equation 4.2 can be rewritten as follows:

$$\left(\frac{C^k_{a,i}+C^k_{a,i}\mu^k_{a,i}}{C^k_{a,r}+C^k_{a,r}\mu^k_{a,r}}\right)\Bigg/\left(\frac{C^k_{b,i}+C^k_{b,i}\mu^k_{b,i}}{C^k_{b,r}+C^k_{b,r}\mu^k_{b,r}}\right)=\left(\frac{1+\tau^k_{a,i}+\left(1+\tau^k_{a,i}\right)\kappa^k_{a,i}}{1+\tau^k_{a,r}+\left(1+\tau^k_{a,r}\right)\kappa^k_{a,r}}\right)^{-\eta^k_a}\Bigg/\left(\frac{1+\tau^k_{b,i}+\left(1+\tau^k_{b,i}\right)\kappa^k_{b,i}}{1+\tau^k_{b,r}+\left(1+\tau^k_{b,r}\right)\kappa^k_{b,r}}\right)^{-\eta^k_b} \tag{4.3}$$

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

$$\log\left(\frac{C^k_{a,i}}{C^k_{a,r}}\right)-\log\left(\frac{C^k_{b,i}}{C^k_{b,r}}\right)=-\eta^k_a\log\left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right)+\eta^k_b\log\left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right)+\log\left(\psi^k_{a,b,i,r}\right) \tag{4.4}$$

where $\psi^k_{a,b,i,r}=\frac{(1+\mu^k_{a,r})(1+\mu^k_{b,i})}{(1+\mu^k_{a,i})(1+\mu^k_{b,r})}\left(\frac{1+\kappa^k_{a,i}}{1+\kappa^k_{a,r}}\right)^{-\eta^k_a}\left(\frac{1+\kappa^k_{b,r}}{1+\kappa^k_{b,i}}\right)^{-\eta^k_b}$. This expression can be estimated by ordinary least squares (OLS) when $\frac{(1+\mu^k_{a,r})(1+\mu^k_{b,i})}{(1+\mu^k_{a,i})(1+\mu^k_{b,r})}=\left(\frac{1+\kappa^k_{a,i}}{1+\kappa^k_{a,r}}\right)^{\eta^k_a}\left(\frac{1+\kappa^k_{b,r}}{1+\kappa^k_{b,i}}\right)^{\eta^k_b}\xi^k_{a,b,i,r}$, where $\xi^k_{a,b,i,r}$ is a random variable statistically independent of the regressors. In such a case, $\psi^k_{a,b,i,r}=\xi^k_{a,b,i,r}$ and therefore is statistically independent of the regressors.

If there is a zero trade observation, say $C^k_{a,i}=0$, Equation 4.2 can be rewritten as follows:

$$\left(\frac{\upsilon^k_{a,i}}{C^k_{a,r}+C^k_{a,r}\mu^k_{a,r}}\right)\Bigg/\left(\frac{C^k_{b,i}+C^k_{b,i}\mu^k_{b,i}}{C^k_{b,r}+C^k_{b,r}\mu^k_{b,r}}\right)=\left(\frac{1+\tau^k_{a,i}+\left(1+\tau^k_{a,i}\right)\kappa^k_{a,i}}{1+\tau^k_{a,r}+\left(1+\tau^k_{a,r}\right)\kappa^k_{a,r}}\right)^{-\eta^k_a}\Bigg/\left(\frac{1+\tau^k_{b,i}+\left(1+\tau^k_{b,i}\right)\kappa^k_{b,i}}{1+\tau^k_{b,r}+\left(1+\tau^k_{b,r}\right)\kappa^k_{b,r}}\right)^{-\eta^k_b} \tag{4.5}$$

If the log of both sides are taken, the following is obtained:

$$-\log\left(C^k_{a,r}\right)-\log\left(\frac{C^k_{b,i}}{C^k_{b,r}}\right)=-\eta^k_a\log\left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right)+\eta^k_b\log\left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right)+\log\left(\psi^{k\prime}_{a,b,i,r}\right) \tag{4.6}$$

where $\psi^{k\prime}_{a,b,i,r}=\frac{(1+\mu^k_{a,r})(1+\mu^k_{b,i})}{\upsilon^k_{a,i}(1+\mu^k_{b,r})}\left(\frac{1+\kappa^k_{a,i}}{1+\kappa^k_{a,r}}\right)^{-\eta^k_a}\left(\frac{1+\kappa^k_{b,r}}{1+\kappa^k_{b,i}}\right)^{-\eta^k_b}$. This expression can be estimated by ordinary least squares (OLS) when $\frac{(1+\mu^k_{a,r})(1+\mu^k_{b,i})}{\upsilon^k_{a,i}(1+\mu^k_{b,r})}=\left(\frac{1+\kappa^k_{a,i}}{1+\kappa^k_{a,r}}\right)^{\eta^k_a}\left(\frac{1+\kappa^k_{b,r}}{1+\kappa^k_{b,i}}\right)^{\eta^k_b}\xi^k_{a,b,i,r}$, where $\xi^k_{a,b,i,r}$ is a random variable statistically independent of the regressors. In such a case, $\psi^k_{a,b,i,r}=\xi^k_{a,b,i,r}$ 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.

4.1.2. Additive Measurement Errors

Although OLS is consistent under the assumptions made (i.e., assuming that error terms are additive for zero trade observations and multiplicative for nonzero trade observations), for robustness, a unique additive error term is also considered. In such a case:

$$\left(\frac{C^k_{a,i}}{C^k_{a,r}}\right) \Big/ \left(\frac{C^k_{b,i}}{C^k_{b,r}}\right) = \left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right)^{-\eta^k_a} \Big/ \left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right)^{-\eta^k_b} + \mu^k_{a,b,i,r} \tag{4.7}$$

where $E\left[\mu^k_{r,a,b,j} \,\middle|\, \frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}, \frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right] = 0$. This can be rewritten as:

$$\left(\frac{C^k_{a,i}}{C^k_{a,r}}\right) \Big/ \left(\frac{C^k_{b,i}}{C^k_{b,r}}\right) = \left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right)^{-\eta^k_a} \Big/ \left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right)^{-\eta^k_b} \upsilon^k_{a,b,i,r} \tag{4.8}$$

where

$$\upsilon^k_{a,b,i,r} = 1 + \frac{\mu^k_{a,b,i,r}}{\left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right)^{-\eta^k_a} \Big/ \left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right)^{-\eta^k_b}} \tag{4.9}$$

and $E\left[\upsilon^k_{a,b,i,r} \,\middle|\, \frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}, \frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right] = 1$. Taking the log of both sides in Equation 4.8 results in the following log-linear expression:

$$\log\left(\frac{C^k_{a,i}}{C^k_{a,r}}\right) - \log\left(\frac{C^k_{b,i}}{C^k_{b,r}}\right) = -\eta^k_a \log\left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right) + \eta^k_b \left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right) + \log\left(\upsilon^k_{a,b,i,r}\right) \tag{4.10}$$

To obtain a consistent estimator of the slope parameters by OLS, it is assumed that $E\left[\log\left(\upsilon^k_{a,b,i,r}\right) \,\middle|\, \frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}, \frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right]$ does not depend on the regressors.[14] Because of Equation 4.9, this condition is met only if $\mu^k_{a,b,i,r}$ can be written as follows:

$$\mu^k_{a,b,i,r} = \left(\left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right)^{-\eta^k_a} \Big/ \left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right)^{-\eta^k_b}\right) \xi^k_{a,b,i,r}$$

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

Until now, the conditions under which OLS can be used as an estimation method have been introduced. Nevertheless, for robustness, following Santos Silva and Tenreyro (2006), the assumption of $E\left[\log\left(\upsilon^k_{a,b,i,r}\right) \,\middle|\, \frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}, \frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right]$ not depending on the regressors is also relaxed 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 4.8 can be written as follows:

$$\left(\frac{C^k_{a,i}}{C^k_{a,r}}\right) \Big/ \left(\frac{C^k_{b,i}}{C^k_{b,r}}\right) = \exp\left(-\eta^k_a \log\left(\frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}\right) + \eta^k_b \log\left(\frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right)\right) \upsilon^k_{a,b,i,r} \tag{4.11}$$

Assuming $E\left[\upsilon^k_{a,b,i,r} \,\middle|\, \frac{1+\tau^k_{a,i}}{1+\tau^k_{a,r}}, \frac{1+\tau^k_{b,i}}{1+\tau^k_{b,r}}\right] = 1$, then Equation 4.11 may be estimated consistently using the PPML estimator.

In sum, two different estimation methods are considered in the estimation of Equation 4.1: 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, it is not a concern here, 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 measurement error, the issue of zero trade observations can be handled by setting zero trade observations equal to one. This assumption is necessary mostly because the log of zero and a division by zero are both unidentified.

4.2. 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 by using Equation 2.3:

$$\eta_a^k = \varepsilon_a^k \left(1 + \tau_{a,i}^k\right) \tag{4.12}$$

Equation 4.12 is estimated by using the very same methodology that is used to estimate Equation 4.1. For robustness, again, two different types of measurement errors are considered: proportional and additive.[16]

4.2.1. Proportional Measurement Errors

In particular, if the measurement errors (of trade costs) are multiplicative, Equation 4.12 can be rewritten as follows:

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

Taking the log of both sides results in:

$$\log \eta_a^k = \log \left(\varepsilon_a^k \left(1 + \tau_{a,i}^k\right)\right) + \log \psi_{a,i}^k$$

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

4.2.2. Additive Measurement Errors

Alternatively, if there is a unique additive error term, Equation 4.12 can be rewritten as follows:

$$\eta_a^k = \varepsilon_a^k \left(1 + \tau_{a,i}^k\right) + \mu_{a,i}^k$$

This can be rewritten as:

$$\eta_a^k = \varepsilon_a^k \left(1 + \tau_{a,i}^k\right) \upsilon_{a,i}^k \tag{4.13}$$

where

$$\upsilon_{a,i}^k = 1 + \frac{\mu_{a,i}^k}{\varepsilon_a^k \left(1 + \tau_{a,i}^k\right)} \tag{4.14}$$

and $E\left[\upsilon_{a,i}^k \,\middle|\, \left(1 + \tau_{a,i}^k\right)\right] = 1$. Taking the log of both sides in Equation 4.13 results in the following log-linear expression:

$$\log \eta_a^k = \log \left(\varepsilon_a^k \left(1 + \tau_{a,i}^k\right)\right) + \log \upsilon_{a,i}^k \tag{4.15}$$

To obtain a consistent estimator of the slope parameters by OLS, it is assumed that $E\left[\log\left(\upsilon_{a,i}^k\right) \,\middle|\, \left(1 + \tau_{a,i}^k\right)\right]$ does not depend on the regressors. Because of Equation 4.14, this condition is met only if $\mu_{a,i}^k$ can be written as follows:

$$\mu_{a,i}^k = \varepsilon_a^k \left(1 + \tau_{a,i}^k\right) \xi_{a,i}^k$$

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

The assumption of $E\left[\log\left(\upsilon_{a,i}^k\right) \,\middle|\, \left(1 + \tau_{a,i}^k\right)\right]$ not depending on the regressors is also relaxed by considering the PPML estimator. To show this, Equation 4.13 can be written as follows:

$$\eta_a^k = \exp\left(\log\left(\varepsilon_a^k \left(1 + \tau_{a,i}^k\right)\right)\right) \upsilon_{a,i}^k \tag{4.16}$$

Assuming $E\left[\log\left(\upsilon_{a,i}^k\right) \,\middle|\, \left(1 + \tau_{a,i}^k\right)\right] = 1$, then Equation 4.11 may be estimated consistently using the PPML estimator.

In sum, again, two different estimation methods are considered in order to test the validity of Equation 4.12: OLS and PPML.

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

4.3. Trade Costs

The connection between the model and the empirical analysis in terms of trade costs has to be clarified. 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, trade costs are defined as follows:

$$1+\tau_{a,i}^{k} = \underbrace{\left(D_{a,i}^{k}\right)}_{\text{freight}} \times \underbrace{\left(1+t_{a}^{k}\right)}_{\text{other}} \times \underbrace{\left(1+w_{a}\right)}_{\text{distribution}}$$

where $D_{a,i}^{k}$ is the distance between country a and state i of country k (i.e., the U.S.) to capture the freight costs; t_{a}^{k} is representing the (net) costs related to tariffs (and quotas) from country k (i.e., 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.

4.4. Estimated Equations

By using the definition of trade costs, the final version of Equation 4.1 to be estimated can be introduced as follows:

$$\begin{aligned}\left(\frac{C_{a,i}^{k}}{C_{a,r}^{k}}\right)\Big/\left(\frac{C_{b,i}^{k}}{C_{b,r}^{k}}\right) &= \left(\frac{\left(D_{a,i}^{k}\right)\left(1+t_{a}^{k}\right)\left(1+w_{a}\right)}{\left(D_{a,r}^{k}\right)\left(1+t_{a}^{k}\right)\left(1+w_{a}\right)}\right)^{-\eta_{a}^{k}}\Big/\left(\frac{\left(D_{b,i}^{k}\right)\left(1+t_{b}^{k}\right)\left(1+w_{b}\right)}{\left(D_{b,r}^{k}\right)\left(1+t_{b}^{k}\right)\left(1+w_{b}\right)}\right)^{-\eta_{b}^{k}} \\ &= \left(\frac{D_{a,i}^{k}}{D_{a,r}^{k}}\right)^{-\eta_{a}^{k}}\Big/\left(\frac{D_{b,i}^{k}}{D_{b,r}^{k}}\right)^{-\eta_{b}^{k}} \qquad (4.17)\end{aligned}$$

where η values for each country can be estimated. Note that employing a difference-in-difference approach effectively eliminates the distribution margin and the tariffs (or the quotas) from the theoretical trade equation, which makes the estimation results robust to these issues.

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, the equation can be estimated for each (a,b) country pair separately. Hence, a separate regression is run for each possible (a,b) pair and the estimates coming out of regressions with the highest explanatory powers are selected. For instance, in order to have an estimate of η_a for country a, all possible trade ratios that include country a are considered. Then, among those estimated regressions, the one with the highest explanatory power (in terms of R-bar sqd.) is selected. The corresponding η_a is the one obtained from that regression with the highest explanatory power.

After having measures of η_a's, the relation between η_a and trade costs is tested. In particular, the final version of Equation 4.12 to be estimated can be written as follows:

$$\eta_{a}^{k} = \varepsilon_{a}^{k}\left(D_{a,i}^{k}\right)\left(1+t_{a}^{k}\right)\left(1+w_{a}\right) \qquad (4.18)$$

where economic region specific dummies are used for $\varepsilon_{a}^{k}\left(1+t_{a}^{k}\right)\left(1+w_{a}\right)$'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_{a}^{k} nor $\left(1+t_{a}^{k}\right)\left(1+w_{a}\right)$'s can be identified due to the dummy variable trap. Although having very similar (mostly the same) tariff rates, $\left(1+t_{a}^{k}\right)$'s, are reasonable within the same economic region, one may think that the countries in the same economic region may not share the same ε_{a}^{k}'s and/or the same distribution costs, $(1+w_a)$'s. In such a case, $\varepsilon_{a}^{k}(1+w_a)$ can be thought as a part of the error term (i.e., the unobserved term) in the estimation process where ε_{a}^{k} 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

[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 (2009) who show the local distribution costs are directly related to the wage rates in the distribution sector.

country are 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 $1+\tau_{a,i}^k = \left(D_{a,i}^k\right)^\delta \left(1+t_a^k\right)(1+w_a)$ where δ represents the elasticity of distance. In such a case, the estimated equation would be $\delta\eta_a^k = \delta\varepsilon_a^k \left(D_{a,i}^k\right)^\delta \left(1+t_a^k\right)(1+w_a)$, where $\delta\eta_a^k$ would be the estimate obtained from Equation 4.17. This change would only affect the magnitude of 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 in terms of finding systematic relations across importers. Nevertheless, for robustness, a restriction in which $\delta = 1$ will be tested, below.

4.5. Source Prices

Up to now, the source prices have been set equal to 1 for empirical convenience. This simplicity would have almost no effect on the estimation of Equation 4.1, since the ratio of two source prices is considered there.[18] However, some important information may get lost by doing so when $\eta_a^k = \frac{\varepsilon_a^k\left(P_{k,i}^k+\tau_{a,i}^k\right)}{P_{k,i}^k}$ is estimated 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^k decreases in $P_{k,i}^k$. Thus, anything that affects the source prices also affects η_a^k. 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^k 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^k 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^k).

Although economic region specific dummies are used while testing the relation in Equation 4.18, they may not capture all the country specific variation in η_a^k due to the pricing strategies mentioned above. Hence, consistent with what is 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 4.18 for robustness.

5. Empirical Results

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

[18] According to Equation 4.1, 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.

Table 2 - Estimation of η_a^k

	First Quartile	Median	Third Quartile
η_a^k (OLS)	3.11	7.04	20.57
R-bar sqd. (OLS)	0.36	0.46	0.57
η_a^k (PPML)	10.71	27.34	41.12
R-bar sqd. (PPML)	0.98	0.98	0.99

As is evident, while the median OLS estimate of η_a^k is 7.04, the median PPML estimate of η_a^k 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^k (i.e., 7.04) is close to the estimates in the literature, the median PPML estimate of η_a^k (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.

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

In all regressions, only uncorrelated variables are included 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^k, is not constant across countries. In particular, EDD increases in trade costs and decreases in the source prices. Hence, the 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.

[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.

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

	Dependent Variable: $\log(\eta_a^k)$												
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. Since we have a two-stage estimation procedure, the biased OLS standard errors are corrected according to Dumont et al. (2005) and they are given 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.

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, as a summary of both tables, 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.

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

	Dependent Variable: $\log(\eta_a^k)$												
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.

Comparison with Hummels and Lugovskyy (2009)

The empirical results are compared with the results of Hummels and Lugovskyy (2009; 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:

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

and

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

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. The possible issues related to their log-linear estimation approach have already been discussed in the introduction, they won't be repeated here. Instead, the explanatory power of this paper will be compared with theirs by using the data of this paper.

If the regression analysis of HL is replicated by using the data of this paper, the results in Table 5 are obtained. While the first two columns of Table 5 show the results of HL for comparison, the other columns show the results of this paper. 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 HL estimates are significant and have their expected signs, the explanatory power of their OLS estimation is too low compared to the results of this paper in Table 3. When their method is replicated by using the data of this paper (i.e., by including both GDP and GDP per capita into the regression), the results in column 3 are obtained, 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 the alternative regression of HL is replicated by using the data of this paper (i.e., by including GDP per capita and population into the regression), the results in columns 5 and 6 are obtained. In column 5, where OLS is used, the results of this paper 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 the OLS results of this paper in Table 3. When the PPML estimation is employed in column 6, a high R-bar sqd. value is obtained, but this time the signs of the estimates are not as expected from the theory of HL. And, compared to the explanatory powers in Table 4, this regression has a lower power.

Table 5 - Comparison with HL

	Dependent Variable							
	η_a^k	$\log(\eta_a^k)$	η_a^k	η_a^k	$\log(\eta_a^k)$	$\log(\eta_a^k)$	$\log(\eta_a^k)$	$\log(\eta_a^k)$
	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. Since we have a two-stage estimation procedure, the biased OLS standard errors are corrected according to Dumont et al. (2005). 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, an alternative regression is run in the following form:

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

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 obtained by using the data of this paper 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 column 8 is considered, 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 the results of this paper in Table 4.

In sum, the data of this paper cannot be explained enough by using the method of HL. Instead, when Table 5 is compared with Table 3 and Table 4, the method of this paper provides much more explanation compared to the method of HL. The alternative regressions for robustness support this result.

6. Policy Implications

What are the policy implications of the empirical results of this paper? In order to answer this question, importer specific Armington elasticities are compared with the constant Armington elasticity that is largely used in the literature. A constant Armington elasticity measure has to be calculated for this comparison. Therefore, a special case of Equation 4.1 in which $\eta_a^k = \eta_b^k = \eta^k$ for all a, b is estimated:

$$\left(\frac{C_{a,i}^k}{C_{a,r}^k}\right) \Big/ \left(\frac{C_{b,i}^k}{C_{b,r}^k}\right) = \left(\left(\frac{1+\tau_{a,i}^k}{1+\tau_{a,r}^k}\right) \Big/ \left(\frac{1+\tau_{b,i}^k}{1+\tau_{b,r}^k}\right)\right)^{-\eta^k} \tag{6.1}$$

A very similar econometric methodology that is used to estimate Equation 6.1 is employed. In particular, after taking average of trade (i.e., export) ratios over time (between 1999 and 2007), since η^k is common across importers, one can estimate a pooled sample of all observations. However, since it is a question of which (a, b) ratios to take in the difference-in-difference approach, the pool of all possible (a, b) ratios is considered in the estimation.[20]

It is found that the OLS estimate of η^k is around 2.95 and the PPML estimate of η^k is around 4.89.[21] The OLS (PPML) estimate of η^k suggests that a 1% increase in destination prices leads to around 3% (5%) of a fall in quantity demanded by all importers. Considering the fact that the data consist of the exports of the U.S. states, these results are true for any state of the U.S. (thus, the overall U.S. exports at the national level) under the assumption of a constant Armington elasticity.

In order to make a comparison between the constant Armington elasticity and the importer-specific-Armington elasticities introduced in this paper, it is necessary to show the effects of a 1% increase in destination prices on the quantity demanded for U.S. exports under importer-specific-Armington elasticities. In order to calculate the percentage fall in quantity demanded, first the average exports of each U.S. state to 230 countries between 1999 and 2007 are calculated. Then, the importer-specific-Armington-elasticity weighted sum of the exports of each state are calculated; for each state, the obtained number is the fall in quantity demanded after a 1% increase in destination prices. After obtaining the fall in quantity demanded for each state, one can easily calculate the percentage fall in exports at the U.S. state level and at the U.S. national level by using the original export data. When this analysis is employed by using the importer-specific-Armington-elasticity OLS (PPML) estimates found in the previous section, it is found that the fall in quantity demanded for U.S. exports (at the national level) after a 1% increase in destination prices is around 9% (20%), which is much higher than the constant Armington elasticity

[20] Since zero trade observations are taken care of in the way discussed above, pooling all possible (a, b) ratios would give more robust results compared to considering only independent (a, b) ratios. By this way, a selection problem (e.g., alphabetical or distance weighted or country size weighted) for (a, b) ratios also disappears.

[21] Both of these estimates are highly significant.

implication of 3% (5%). Similarly, again after a 1% increase in destination prices, the fall in quantity demanded for U.S. exports at the state level is around 10% (20%) on average (taken across states) by using importer specific Armington elasticity OLS (PPML) estimates.[22] In other words, the constant Armington elasticity dramatically undervalues the effects of a price change on the U.S. exports.

These results correspond to important policy implications at both the state level and the national level U.S. exports. For instance, at the national level, after an increase in trade costs (say, through foreign tariffs determined by international trade policies), the implied changes in quantity demanded by the constant Armington elasticity is around 3 or 4 times lower than the one implied by the importer-specific Armington elasticities. As another example, at the state or national level, after an increase in source prices (say, through regional or national tax policies), the implied changes in quantity demanded by the constant Armington elasticity is again around 3 or 4 times lower than the one implied by the importer-specific Armington elasticities. As is evident, these differences are at significant levels and should be considered by policy authorities, at the state level, the national level, and the international level.

7. Conclusions

This paper attempts to analyze whether or not the elasticity of substitution across goods changes from one importer country to another in the context of Armington aggregators in international trade. Under the assumption of a 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, it is shown, 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 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 source prices.

The results of this paper also correspond to important policy implications at both the U.S. state level and the U.S. national level: individual responses of the importers should be taken into account. In particular, an increase in trade costs at the international level or an increase in taxes at the state or national level leads to higher prices in the destination (i.e., the importer) countries. The effect of these price changes on the quantity demanded for U.S. exports is undervalued around 3 or 4 times when a constant Armington elasticity is used compared to importer-specific Armington elasticities. These differences are at significant levels and should be considered by policy authorities, at the state, national, and international levels.

Nevertheless, this paper has analyzed only the long-run properties of the Armington elasticity. Many things remain to be done in future research. This includes an analysis depicting the short-run properties of the Armington elasticity and an analysis using data at a more micro level. While the former would be useful in the context of international business cycle literature, the latter would provide more insight to understanding the properties of good specific Armington elasticities, and thus good specific trade policies.

[22] To save space, only the results at the U.S. national level or the average of the U.S. state level are depicted, but the individual results at the state level, which are important for regional policies such as tax rates, are also available upon request.

References

[1] Alessandria J. and Kaboski, J.P. “Violating Purchasing Power Parity” Federal Reserve Bank Working Paper No. 04-19, 2004.

[2] Anderson, DR, Sweeney, DJ, and Williams, TA, (2006), Essentials of Statistics for Business and Economics, Thomson South-Western.

[3] Anderson, J.E., and Wincoop, E.V., (2004), "Trade Costs", *Journal of Economic Literature*, 42: 691-751.

[4] Armington, P. S. (1969), "A Theory of Demand for Products Distinguished by Place of Production," International Monetary Fund Staff Papers, 16(1), 159-178.

[5] Brander, J. and Krugman, P., (1982), "A Reciprocal Dumping Model of International Trade", *Journal of International Economics*, 15: 313-321.

[6] Hickman, BG, and Lau, LJ, (1973), Elasticities of Substitution and Export Demands in a World Trade Model, European Economic Review, 4: 347-380.

[7] Broda, C., and Weinstein, D.E., (2006), "Globalization and the Gains from Variety", *Quarterly Journal of Economics*, 121(2): 541-585.

[8] Cassey, AJ, (2006), State Export Data: Origin of Movement vs. Origin of Production, *mimeo.*

[9] Chang,TC, (1948), "A statistical note on world demand for exports," The Review of Economics and Statistics, 30: 106-116.

[10] Chou, JJ, and Buongiorno, J, (1983), "United States Demand for Hardwood Plywood Imports by Country of Origin", Forest Science, 29(2): 225-237.

[11] Coughlin CC, Mandelbaum TB (1991) Measuring state exports: Is there a better way? Federal Reserve Bank of St. Louis Review 73:65-79

[12] Coughlin, CC, Wall, HJ, (2002), "NAFTA and the Changing Pattern of State Exports", Federal Reserve Bank of St. Louis Working Paper 2000-029B.

[13] Cronovich R, Gazel RC (1999) How reliable are the MISER foreign trade data? *mimeo.*

[14] Crucini, M.J., and Yilmazkuday, H., (2009), "A Model of International Cities: Implications for Real Exchange Rates", NBER Working Paper No 14834.

[15] Dekle, R., Eaton, J., and Kortum, S., (2008), "Global Rebalancing with Gravity: Measuring the Burden of Adjustment," NBER Working Paper No 13846.

[16] Dixit, Avinash K. and Stiglitz, Joseph E., (1977), "Monopolistic Competition and Optimal Product Diversity", *American Economic Review*, 67(3): 297-308.

[17] Dumont, Michel, Glen Rayp, Oliver Thas and Peter Willemé (2005) “Correcting Standard Errors in Two-Stage Estimation Procedures with Generated Regressands,” Oxford Bulletin of Economics and Statistics 67: 421-33.

[18] Eaton, J., and Kortum, S., (2002), "Technology, Geography and Trade", *Econometrica*, 70(5): 1741-1779.

[19] Feenstra, R. C. “Symmetric Pass-Trough of Tariffs and Exchange Rates Under Imperfect Competition: An Empirical Test.” Journal of International Economics, 1989, 16, 227-42.

[20] Feenstra, R.C. “New Product Varieties and the Measurement of International Prices,” American Economic Review 84, March 1994, 157-177.

[21] Gallaway, Michael P. , McDaniel, Christine A., and Rivera, Sandra A., (2003), "Short-run and long-run industry-level estimates of U.S. Armington elasticities", *North American Journal of Economics and Finance* 14: 49–68.

[22] Goldberg, P. and Knetter, M. "Goods Prices and Exchange Rates: What Have We Learned?" Journal of Economic Literature, September 1997, 35(3): 1243-72.

[23] Gordon, R. J. (1990), "What Is New-Keynesian Economics?" Journal of Economic Literature 28: 1115-1171.

[24] Gorman, WM, (1958), "Tariffs, Retaliation, and the Elasticity of Demand for Imports", The Review of Economic Studies, 25(3): 133-162

[25] Greenhut, ML, Norman, G., and Hung, CS, (1987), "The Economics of Imperfect Competition: A Spatial Approach", Cambridge University Press.

[26] Harrigan, J., (1996), "Openness to Trade in Manufactures in the OECD", *Journal of International Economics*, 40: 23-39.

[27] Hayward DJ, Erickson RA (1995) The North American trade of US states: A comparative analysis of industrial shipments, 1983-1991. International Regional Science Review 18:1-31

[28] 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.

[29] Helpman, E., Melitz, M. and Rubinstein, Y., (2008), "Estimating Trade Flows: Trading Partners and Trading Volumes", *Quarterly Journal of Economics,* 123(2): 441–487.

[30] Henderson, D.J. and Millimet, D.L., (2008), "Is gravity linear?," *Journal of Applied Econometrics*, 23(2): 137-172.

[31] Hummels, D., (2001), "Toward a Geography of Trade Costs", *mimeo.*

[32] Hummels, D., and Lugovskyy, V., (2009), "International Pricing in a Generalized Model of Ideal Variety", *Journal of Money, Credit and Banking*, 42(s1): 3-33.

[33] Johnson, HG, (1953-1954), "Optimum Tariffs and Retaliation," The Review of Economic Studies, 21(2): 142-153.

[34] Knetter, M. M. "International Comparison of Pricing-to Market Behavior." American Economic Review, June 1993, 83(3), 473-89.

[35] "The Elasticity of Substitution as a Variable in World Trade" (Kravis, I.B. and Lipsey R.E.), in International Comparisons of Prices and Output, ed. by D. J. Daly, Studies in Income and Wealth, Vol. 37, NBER, 1972, pp. 369-398.

[36] Irving B. Kravis, Robert E. Lipsey, The Role of the Computer in Economic and Social Research in Latin America (1975), Nancy D. Ruggles, ed. (p. 253 - 268) Published in 1975

[37] Mordechai E. Kreinin, Price Elasticities in International Trade, The Review of Economics and Statistics, Vol. 49, No. 4, (Nov., 1967), pp. 510-516.

[38] Matsuyama, K. "Complementarities and Cumulative Processes in Models of Monopolistic Competition." Journal of Economic Literature Vol. 33, (June 1995), pp. 701-729.

[39] McDaniel, CA., and Balistreri, EJ, 2002, "A Discussion on Armington Trade Substitution Elasticities," USITC Working Paper 2002-01-A (Washington: United States International Trade Commission).

[40] Note on the Measurement of Elasticity of Substitution in International Trade, J. J. Polak, The Review of Economics and Statistics, Vol. 32, No. 1 (Feb., 1950), pp. 16-20.

[41] Richardson, JD, (1972), "On Improving the Estimate of the Export Elasticity of Substitution", The Canadian Journal of Economics, 5(3): 349-357.

[42] Richardson, JD, (1973), "Beyond (But Back to) the Elasticity of Substitution in International Trade", European Economic Review, 4: 381-392.

[43] Romalis, J., (2007), "NAFTA's and CUSFTA's Impact on International Trade", *The Review of Economics and Statistics*, 89(3): 416-435

[44] Ruhl, KJ (2008), "The International Elasticity Puzzle", *mimeo.*

[45] Santos Silva, J. M. C. and Tenreyro, S., (2006). "The Log of Gravity," *The Review of Economics and Statistics*, 88(4): 641-658.

[46] Syropoulos, C., (2002),,"Optimum Tariffs and Retaliation Revisited: How Country Size Matters", The Review of Economic Studies, 69(3): 707-727.

[47] Tinbergen, J., (1946), "Some Measurements of Elasticities of Substitution", The Review of Economic Statistics, 28(3): 109-116

[48] Zissimos, B. (2008), "Optimum Tariffs and Retaliation: How Country Numbers Matter", *mimeo.*

8. Appendix

This section shows that, under additive trade costs, EDD is the sum of EDS and EDT, for any type of demand function. It is also shown that EDD is increasing in EDS and trade costs, and it is decreasing in source prices, again for any type of demand function.

Consider the following general type demand function:

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

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:

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

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

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

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, one can write:

$$\text{EDD} = \left(\frac{P+\tau}{P}\right)\text{EDS} \tag{8.1}$$

which means that EDD increases in EDS and trade costs, and it decreases in the source prices, *ceteris paribus*.