Understanding Interstate Trade Patterns

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Abstract

This paper models interstate trade patterns of U.S. states using a partial equilibrium trade model. The theoretical model deviates from the existing gravity literature by employing trade estimations in ratio form, with the ratio of imports from different sources, rather than the level of bilateral trade between two locations. Using this specification, together with considering the production side through technology levels, the elasticity of substitution across goods, the elasticity of substitution across varieties of each good, and the good specific elasticity of distance measures are all identified in the empirical analysis, which is not the case in gravity type studies. The ratio transformation also effectively eliminates any proportional distribution margin, international trade, or overstatement of distance measures from the theoretical trade equation. Compared to empirical international trade literature, the elasticity of substitution is estimated to be lower, while the elasticity of distance is estimated to be higher intranationally.

JEL Classification: R12, R13, R32

Key Words: Trade Ratios; Transportation; The United States

1. Introduction

What is the main motivation behind intranational trade? Compared to *relatively* complex models in the literature, this paper contributes by introducing a simple partial equilibrium model to analyze the motivations behind bilateral trade patterns of regions at the *disaggregate* level. It is attempted to find why regions do import more goods from some regions while importing fewer from others. It is also investigated why a region imports more of a good while importing less of another one. A monopolistic competition model consisting of a finite number of regions is employed. There are two types of goods, traded and nontraded. Each region produces and consumes a unique nontraded good. Each region may also consume all varieties of all traded goods, while it can produce only one variety of each traded good. While the traded goods are produced by a perfectly mobile unique factor, the only nontraded good in each region is produced by the same mobile factor together with traded intermediate inputs. According to this setup, as is standard in the literature, it is shown that the trade of a variety of a particular traded good across any two regions depend on the relative price of the variety and the total demand (final consumption demand plus intermediate input demand) of the good in the destination (importer) region. The nuance of this paper comes into the picture when the ratio between imports of varieties from different sources (exporters) is considered. It is found that a region imports more goods (measured in values) from the lower price regions and fewer goods from the more distant regions.

Considering the ratio between imports of varieties from different sources (rather than the level of bilateral trade between two locations) has several empirical and analytical benefits compared to gravity models in the following senses:

(i) There is no identification problem in terms of estimating the elasticity of substitution and the elasticity of distance at the same time. However, even Anderson and van Wincoop's (2003) most popular gravity model suffers from this problem (also see Wei 1996; Hummels 1999, 2001). By distinguishing between aggregate level and disaggregate level trade data, together with considering the production side of the model, the elasticity of substitution across goods can also be estimated. The main idea is to exploit (implicit) variation in prices (which

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can be proxied by variation in inferred technology parameters that are imputed from data on production and cost of living data) across origins to pin down the elasticity of substitution across varieties. Having pinned down the elasticity of substitution across varieties, independently of distance, one can identify the elasticity of distance directly off the estimated distance coefficient.

(ii) The methodology controls for a possible issue of overstating the distance measures (due to using calculated distances, such as great circle distances) mentioned by Hillberry and Hummels (2001), given the overstatement is proportional to the actual distance measures.

(iii) By construction, the model is capable of controlling for the proportional effects of local (i.e., wholesale and retail) distribution costs, insurance costs, local taxes, markup differences in production, international trade (under reasonable assumptions), and intermediate input trade, each of which are possible topics for separate debates in the literature (see Anderson and van Wincoop 2004).

(iv) There is an exogenous solution for the estimated trade expression, and thus, there is no need for any income data for estimation, *given* the technological levels. This convenient feature of the model also makes the estimation free of a possible endogeneity problem.

The model is estimated using bilateral trade data belonging to the states of the U.S. The estimated parameters correspond to: a) elasticity of substitution across varieties of a good, each produced in a different region; b) elasticity of substitution across goods, each consisting of different varieties; c) elasticity of distance, which governs good specific trade costs; and d) heterogeneity of individual tastes, governing geographic barriers and the so-called *home-bias*. Several strategies are pursued to estimate these parameters and the results are supported with different sensitivity analyses. Overall, the model is capable of explaining the interstate trade data up to 84% at the disaggregate level, and up to 77% at the aggregate level.

The estimated parameters give insights about a number of issues related to interstate trade patterns within the U.S.: a) compared to empirical international studies, elasticity of substitution is lower intranationally; b) compared to empirical international studies, elasticity of distance is higher intranationally; c) there is evidence of home-bias even at the intranational level; d) trade costs are mostly good specific even at the intranational level; e) source-specific fixed effects are important for bilateral trade patterns, effects usually ignored in the literature; f) production technologies are both good and region specific rather than country specific; g) elasticity of substitution across varieties is good specific.

Related Literature

This subsection describes how this paper relates to its closest antecedents, especially gravity type studies. The gravity models are popular mostly due to their empirical success.[1] When the theoretical background of gravity type studies is considered, Anderson (1979) is the first one to model gravity equations. The main motivation behind Anderson's (1979) gravity model is the assumption that each region is specialized in the production of only one good.[2] Despite its empirical success, as Anderson and van Wincoop (2003) point out, the specialization assumption suppresses finer classifications of goods, and thus makes the model useless in explaining the trade data at the disaggregate level. Another deficiency of Anderson's (1979) gravity model is the lack of a production side. Bergstrand (1985) bridges this gap by introducing a one-factor, one-industry, N-country general equilibrium model in which the production side is considered. In his following study, Bergstrand (1989) extends his earlier gravity model to a two-factor, two-industry, N-country gravity model.[3]

The main deficiency of the gravity models is that they cannot control for good specific transportation costs, good specific local (i.e., wholesale and retail) distribution costs, good specific insurance costs, good specific local taxes, region specific markup differences in production, good specific intermediate input trade or international trade. Moreover, one cannot estimate the elasticity of substitution and the elasticity of distance at the same time using gravity equations. However, this paper controls for all of these situations.

None of the papers mentioned above empirically deal with the trade patterns within a country. Recently, Wolf (2000), Hillberry and Hummels (2001), and Millimet and Thomas (2007) bridged this gap by analyzing the interstate trade patterns within the U.S. However, these studies have a deficiency, because they use the aggregate level (i.e., total bilateral) trade data, while this paper uses disaggregate level bilateral data that give more insight related to good specific analyses. Another deficiency of these studies is that they use gravity type models which suffer from the same issues mentioned above. Also, these studies cannot distinguish between the elasticity of substitution

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[1]Deardorff (1984) reviews the earlier gravity literature. For recent applications, see Wei (1996), Jensen (2000), Rauch (1999), Helpman (1987), Hummels and Levinsohn (1995), and Evenett and Keller (2002).

[2]In the Appendix of his paper, Anderson (1979) extends his basic model to a model in which multiple goods are produced in each region.

[3]Also see Suga (2007) for a monopolistic-competition model of international trade with external economies of scale, Lopez et al. (2006) for an analysis on home-bias on U.S. imports of processed food products, and Gallaway et al. (2003) for an empirical study to estimate short-run and long-run industry-level U.S. Armington elasticities.

across varieties of a good, elasticity of substitution across goods, and the elasticity of distance at the same. By taking the ratio between imports of varieties from different origins (exporters), by taking the ratio between imports of different goods, and by including intermediate input trade into the model, this paper takes care of all of these issues by construction.

Nevertheless, this paper is not the first one that considers trade ratios. For instance, studies such as Head and Ries (2001), Head and Mayer (2002), Eaton and Kortum (2002), and Romalis (2007), among others, have also considered trade ratios in their gravity type models. Most of these studies have attempted to eliminate price measures from the gravity equation since they see them as nuisances. In order to get rid of those price measures, one cannot simply take the ratio among imports of varieties from different origins; they also have to consider the ratio among imports of varieties within regions. This process results in having an index of freeness of trade that determine the impacts of borders (mostly related to international trade literature) rather than explaining the intranational trade patterns. Although this approach seems fine up to a point, it has the deficiency of not considering the production side at all and not having a structure to analyze the disaggregate level trade. The closest study to this paper is by Romalis (2007). However, by eliminating the source specific marginal costs (i.e., the production side), Romalis (2007) cannot identify the elasticity of substitution and the elasticity of distance at the same time; instead, he can only estimate the elasticity of substitution. By considering the production side, this paper can estimate the elasticity of substitution and the elasticity of distance at the same time. Moreover, all of these studies also don't take into account zero trade observations that have a high share in overall observations.[4] This paper contributes to the literature by controlling for all of these issues, therefore by having accurate empirical results.

Plan of the Paper

The rest of the paper is organized as follows. Section 2 introduces a regional trade model. Section 3 introduces data. Section 4 provides insights and depicts the estimation methodology. Section 5 depicts empirical results, while Section 6 concludes.

2. The Model

An economy consisting of a finite number of regions is modeled. In each region, there are two types of goods, traded and nontraded. While a unique nontraded good is produced and consumed within all regions (thus, the nontraded goods market is in equilibrium in each region separately), each region may consume all varieties of all traded goods and can produce only one variety of each traded good. Since the partial equilibrium bilateral trade implications of the model is sufficient for an empirical analysis, in many instances, the irrelevant details of the model are skipped to keep the model more trackable.

Each traded good is denoted by $j = 1, ..., J$. Each variety is denoted by i that is also the notation for the region producing that variety. The analysis is made for a typical region, r. In the model, generally speaking, $H_{a,b}(j)$ stands for the variable H, where a is related to the region of consumption, b is related to the variety (and thus, the region of production), and j is related to the good.

2.1. Individuals

The representative agent in region r maximizes utility $U\left(C_r^T, C_r^{NT}\right)$ where C_r^T is a composite index of traded goods and C_r^{NT} is a unique nontraded good. The composite index of traded goods, C_r^T, is given by:

$$C_r^T \equiv \left(\sum_j (\gamma_j)^{\frac{1}{\varepsilon}} \left(C_r^T(j)\right)^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}$$

where $C_r^T(j)$ is given by:

$$C_r^T(j) \equiv \left(\sum_i (\beta_r \theta_i)^{\frac{1}{\eta(j)}} \left(C_{r,i}^T(j)\right)^{\frac{\eta(j)-1}{\eta(j)}} \right)^{\frac{\eta(j)}{\eta(j)-1}}$$

where $C_{r,i}^T(j)$ is the variety i of traded good j imported from region i; $\varepsilon > 0$ is the elasticity of substitution across goods; $\eta(j) > 1$ is the elasticity of substitution across varieties of good j; γ_j is a good specific taste parameter; β_r is a destination (i.e., importer) specific taste parameter; and finally, θ_i is a source (i.e., exporter) specific taste parameter. For different varieties, while having only one bilateral taste parameter, which is both destination and

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[4]Helpman et al. (2008) show that almost 50% of the observations are zero trade observations in international trade.

source specific, is standard in the literature, decomposing it into β_r and θ_i is new in this paper.[5] In particular, both β_r and θ_i can be used as fixed effects in a regression analysis; i.e., they together represent a unique bilateral taste parameter between regions r and i. Moreover, by putting restrictions on θ_i, one can easily measure home-bias implications of the model. Besides, one can also control for issues such as migration by using θ_i (see Millimet and Thomas, 2007). For robustness, the validity of this assumption is tested in Section 5.

The optimal allocation of any given expenditure within each variety of goods yields the following demand functions:

$$C_{r,i}^T(j) = \beta_r \theta_i \left(\frac{P_{r,i}^T(j)}{P_r^T(j)} \right)^{-\eta(j)} C_r^T(j) \tag{2.1}$$

and

$$C_r^T(j) = \gamma_j \left(\frac{P_r^T(j)}{P_r^T} \right)^{-\varepsilon} C_r^T \tag{2.2}$$

where $P_r^T(j) \equiv \left(\sum_i \beta_r \theta_i P_{r,i}^T(j)^{1-\eta(j)} \right)^{\frac{1}{1-\eta(j)}}$ is the price index of the traded good j (which is composed of different varieties), and $P_r^T \equiv \left(\sum_i \gamma_j P_r^T(j)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$ is the cost of living index in region r. It is implied that $P_r^T(j) C_r^T(j) = \sum_i P_{r,i}^T(j) C_{r,i}^T(j)$.

2.2. Firms

Since there are two types of goods, namely traded and nontraded, there are two types of firms in each region.

2.2.1. Production of Traded Goods

Traded good j in region r (i.e., variety r of good j) is produced by the following production function:

$$Y_r^T(j) = A_r(j) L_r^T(j) \tag{2.3}$$

where $A_r(j)$ represents the good and region specific technology, and $L_r^T(j)$ represents a perfectly mobile factor of production of which hour is worth W in all regions.[6] The firm chooses $L_r^T(j)$, taking as given its price W. The cost minimization problem of the firm implies that the marginal cost of producing variety r of good j (in region r) is given by:

$$MC_r^T(j) = \frac{W}{A_r(j)} \tag{2.4}$$

Note that $MC_r^T(j)$ is good and region specific.

Although having a perfectly mobile factor of production within the same country is a reasonable assumption, a conservative researcher may see it as a strong one; however, it has very convenient empirical implications. In particular, as it will be clearer below, when the ratio of imports from two alternative sources are considered, the price of this factor of production effectively disappears. Nevertheless, the empirical analysis will still have the ratio of source specific technology levels, which captures the ratio of source specific wages up to some degree, because wages are highly correlated with productivity as is well known, especially, in the business cycle literature.[7] In particular, as will be introduced in data section below, when technology level for a particular good is calculated as the value added per labor hour divided by the cost of living index in each region, it is already assumed that real wages, rather than nominal wages, are equalized across regions, because labor responds to real wages, rather than nominal wages, in practice.

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[5] Distinguishing between destination and source specific taste parameters has useful properties in terms of the estimation as shown in Section 4.

[6] One can easily assume $L_r(j)$ to be labor and/or capital, but the results of this paper are not affected at all by these details as we will see below.

[7] In such a case, another problem may arise: if wages are highly correlated with technology levels, and if wages were region specific in Equation 2.4, then the marginal costs of production may be very close to each other across regions. This would correspond to having very similar technology levels across regions in the current version of the model. This possibility is tested in the empirical analysis, and it is shown that the empirical results are robust to this issue.

2.2.2. Production of Nontraded Goods

The unique nontraded good in region r is produced by a production function $Y_r^{NT}\left(L_r^{NT},G_r^{NT}\right)$ where L_r^{NT} represents the completely mobile factor of production (i.e., the same factor used in the production of traded goods) and G_r^{NT} is the counterpart of C_r^T given by:

$$G_r^{NT} \equiv \left(\sum_j \left(\gamma_j\right)^{\frac{1}{\varepsilon}} \left(G_r^{NT}\left(j\right)\right)^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

where $G_r^{NT}\left(j\right)$ is given by:[8]

$$G_r^{NT}\left(j\right) \equiv \left(\sum_i \left(\beta_r\theta_i\right)^{\frac{1}{\eta(j)}} \left(G_{r,i}^{NT}\left(j\right)\right)^{\frac{\eta(j)-1}{\eta(j)}}\right)^{\frac{\eta(j)}{\eta(j)-1}}$$

The optimal allocation of any given expenditure within each variety of intermediate inputs yields the following demand functions:

$$G_{r,i}^{NT}\left(j\right) = \beta_r\theta_i \left(\frac{P_{r,i}^T\left(j\right)}{P_r^T\left(j\right)}\right)^{-\eta(j)} G_r^{NT}\left(j\right) \tag{2.5}$$

and

$$G_r^{NT}\left(j\right) = \gamma_j \left(\frac{P_r^T\left(j\right)}{P_r^T}\right)^{-\varepsilon} G_r^{NT} \tag{2.6}$$

Note that the firms share the same taste parameters, β_r, θ_i and γ_j, with the individuals. Although this is a strong assumption, it has very nice properties in terms of bilateral trade implications that are discussed in Section 4.

2.2.3. Trade Cost

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.). Since this paper considers trade within a country (i.e., the U.S.), the first category can be ignored, and focus is on the second one. Instead of assuming an iceberg transport cost, the transportation is achieved by a transportation sector, which is not modeled here.[9] This assumption is important to distinguish between the export income received by the exporter and the transportation income received by the transporter. The implications of this assumption will be clearer below. In particular, we assume that, if there is a trade between regions, it is subject to a transportation cost:[10]

$$\begin{aligned} P_{i,r}^T\left(j\right) &= \left(1+\tau_{i,r}\left(j\right)\right)\left(P_{r,r}^T\left(j\right)\right) \\ &= \left(D_{i,r}\right)^{\delta(j)}\left(P_{r,r}^T\left(j\right)\right) \end{aligned} \tag{2.7}$$

where $P_{r,r}^T\left(j\right)$ is the price of the traded good at the factory gate (i.e., the source); $\tau_{i,r}\left(j\right) > 0$ is a good specific net transportation cost from region r to region i; $D_{i,r}$ is the distance between regions r and i; and $\delta\left(j\right)$ is the elasticity of distance.[11,12] The cost implications of the model in terms of wholesale distribution, retail distribution, insurance or local taxes, will be provided below.

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[8] Since the bilateral trade implications of the model are sufficient for the empirical analysis, after assuming that the nontraded goods market is in equilibrium in each region, the exact functional forms of $Y_r^{NT}\left(L_r^{NT},G_r^{NT}\right)$, demand for L_r^{NT}, and the marginal cost implication for the nontraded goods are all irrelevant.

[9] Since the partial equilibrium bilateral trade implications of the model are sufficient for the empirical analysis of this paper, the actual role/model of the transportation sector is irrelevant after assuming that transportation is achieved by using the completely mobile factor of production (i.e., the same factor used in the production of traded/nontraded goods).

[10] Needless to say, the existence of trade is determined by Equation 2.1 for all i, r and j. As we will discuss in detail in the following sections, we consider the absence of trade, besides the existence of it in our empirical analysis.

[11] For the distance within each state (i.e., the internal distance), we use the proxy developed by Wei (1996), which is one-fourth the distance of a region's capital from the nearest capital of another region.

[12] See Yilmazkuday (2008) for a theoretical model of transportation which connects $\left(1+\tau_{i,r}\left(j\right)\right)$ to $\left(D_{i,r}\right)^{\delta(j)}$.

2.2.4. Equilibrium

Since the partial equilibrium bilateral trade implications of the model are sufficient for an empirical analysis, the details for equilibrium in nontraded goods market are not depicted here; instead, equilibrium in the traded goods market is shown. In particular, for each variety r of traded good j produced in region r, the market clearing condition implies:

$$Y_r^T(j) = \sum_i C_{i,r}^T(j) + \sum_i G_{i,r}^{NT}(j) \tag{2.8}$$

where $C_{i,r}^T(j)$ is the demand of region i for variety r of traded good j (produced in region r); and $G_{i,r}^{NT}(j)$ is the intermediate input demand for variety r of traded good j (produced in region r) demanded for the production of the nontraded good in region i. Equation 2.8 basically says that variety r of final good j produced in region r is either consumed locally or by other regions, either for final consumption or as an intermediate input.

2.2.5. Price Setting

Since the partial equilibrium bilateral trade implications of the model are sufficient for an empirical analysis, the price setting behavior of the firms producing the unique nontraded good in each region is skipped. For the traded goods, in region r, a typical firm that produces variety r of traded good j faces the following profit maximization problem:

$$\max_{P_{r,r}^T(j)} Y_r^T(j) \left[P_{r,r}^T(j) - MC_r^T(j) \right]$$

subject to Equation 2.8 and the symmetric versions of Equation 2.1 and 2.5. The first order condition for this problem is as follows:[13]

$$Y_r^T(j) \left[1 - \frac{\eta(j)}{P_{r,r}^T(j)} \left(P_{r,r}^T(j) - MC_r^T(j) \right) \right] = 0$$

which implies that:

$$\begin{aligned} P_{r,r}^T(j) &= \left(\frac{\eta(j)}{\eta(j) - 1} \right) MC_r^T(j) \\ &= \left(\frac{\eta(j)}{\eta(j) - 1} \right) \frac{W}{A_r(j)} \end{aligned} \tag{2.9}$$

where $\frac{\eta(j)}{\eta(j)-1}$ represents a good-specific (gross) mark-up.

2.3. Bilateral Trade

In order to depict all implications of the model, it is distinguished between disaggregate and aggregate level trade. While the disaggregate level trade considers bilateral ratios of imports of a region for different varieties of a particular good, the aggregate level trade considers bilateral ratios of imports of different goods for a particular region.

2.3.1. Disaggregate Level Trade

Using Equations 2.1, 2.5 and 2.7, an expression for the ratio of imports of region r from source regions a and b can be obtained as follows:

$$\frac{X_{r,a}(j)}{X_{r,b}(j)} = \frac{\theta_a}{\theta_b} \left(\frac{P_{b,b}^T(j)}{P_{a,a}^T(j)} \right)^{\eta(j)-1} \left(\frac{D_{r,b}}{D_{r,a}} \right)^{\delta(j)\eta(j)} \tag{2.10}$$

where $X_{r,k}(j) = \left(C_{r,k}^T(j) + G_{r,k}^{NT}(j) \right) P_{k,k}^T(j)$ is the value of total imports of region r from region k measured at the source for good j.[14] Equation 2.10 says that a region imports more goods (measured in values) from lower price regions and fewer goods from more distant regions.

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[13]Notice that the firm takes the composite consumption index of good j (i.e., $C_r^T(j)$), the composite index of intermediate demand for good j (i.e., $G_r^{NT}(j)$) and the composite price index of good j (i.e., $P_r^T(j)$) in each region as given in the optimization problem, because the firm is assumed to be too small to have an effect on these variables.

[14]If we had an iceberg cost in our analysis, we would have had $X_{r,k}(j) = \left(C_{r,k}^T(j) + G_{r,k}^{NT}(j) \right) P_{k,k}^T(j) \left(1 + \tau_{r,k}(j) \right)$ as the export income received by the exporter region for good j. However, this is not the case in the real world that distinguishes between the exporter sector and the transportation sector. For instance, the data set of Commodity Flow Survey that is used in the empirical analysis of this paper includes only the export income received by the firms, not the transportation income.

Substituting Equation 2.9 into Equation 2.10 results in the general form of equations for the disaggregated level trade analysis:

$$\frac{X_{r,a}(j)}{X_{r,b}(j)} = \frac{\theta_a}{\theta_b}\left(\frac{A_a(j)}{A_b(j)}\right)^{\eta(j)-1}\left(\frac{D_{r,b}}{D_{r,a}}\right)^{\delta(j)\eta(j)} \tag{2.11}$$

Note that Equation 2.11 is an exogenous solution for the disaggregate level trade expression to be estimated, and thus, there is no need for any endogenous data, such as income, for the estimation, *given* the technology levels. Moreover, it can easily be estimated in log terms.

2.3.2. Aggregate Level Trade

Using Equations 2.2 and 2.6, an expression for the ratio of imports of region r in terms of goods j and k can be obtained as follows:

$$\frac{X_r(j)}{X_r(k)} = \frac{\gamma_j}{\gamma_k}\left(\frac{P_r^T(j)}{P_r^T(k)}\right)^{1-\varepsilon} \tag{2.12}$$

where $X_r(m) = \left(C_r^T(m) + G_r^{NT}(m)\right)P_r^T(m) = \sum_i\left(\left(C_{r,i}^T(m) + G_{r,i}^{NT}(m)\right)P_{i,i}^T(j)D_{r,i}^{\delta(j)}\right)$ is the value of total imports of region r in terms of good m measured at the destination.[15] Equation 2.12 says that a region imports more (less) of a good which has a lower (higher) destination price.

Substituting Equations 2.7, 2.9, and $P_r^T(j) \equiv \left(\sum_i \beta_r \theta_i P_{r,i}^T(j)^{1-\eta(j)}\right)^{\frac{1}{1-\eta(j)}}$ into Equation 2.12 results in the general form of equations to be estimated for the aggregate level trade analysis:

$$\frac{X_r(j)}{X_r(k)} = \frac{\gamma_j}{\gamma_k}\left(\frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right)^{1-\varepsilon} \tag{2.13}$$

Note that Equation 2.13 is an exogenous solution for the aggregate level trade expression, and thus, there is again no need for any endogenous data, such as income, for the estimation, *given* the technology levels. Moreover, it can easily be estimated in log terms after estimating the disaggregate level expression given by Equation 2.11 (i.e., after obtaining estimates for $\eta(j)$'s and $\delta(j)$'s).

3. Data

For the bilateral trade analysis, state-level Commodity Flow Survey (CFS) data obtained from the Bureau of Transportation Statistics for the United States for the year 2002 are used. CFS captures data on shipments originating from select types of business establishments located in all states of the U.S., however, because of data availability, Alaska, District of Columbia and Hawaii are excluded from the analysis. CFS depicts both source and destination states for the value of shipments (i.e., exports) that are measured at the source. This is a perfect match to test the model of this paper, especially through Equation 2.10. The disaggregated level exports data cover 2-digit Standard Classification of Transported Goods (SCTG) commodities of which codes are given in Table 1. In this context, a typical sample from CFS data is the value of shipments of Alcoholic Beverages (of which SCTG code is 8) from New York to California. In CFS, shipments traversing the U.S. from a foreign location to another foreign location (e.g., from Canada to Mexico) are not included. Shipments that are shipped through a foreign territory with both the origin and destination in the U.S. are included in the CFS data.[16] International export (import) shipments are also included in CFS, with the domestic destination (source) defined as the U.S. port, airport, or border crossing of exit from the U.S.; e.g., an international export (import) of an Alcoholic Beverage entering to (exiting from) the U.S. through a port in New York is depicted as a shipment to (from) New York in CFS. This is an important feature of CFS that will be used in the empirical analysis below to control for international exports and imports.

In order to obtain good and region specific technology levels, an approximate mapping (that is officially called a "crosswalk") between 3-digit North American Industry Classification System (NAICS) and 2-digit SCTG obtained from the National Transportation Library of the Bureau of Transportation Statistics is employed. Using this

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[15] Since the data set of Commodity Flow Survey includes only the export income received by the firms, one has to distinguish between the value of exports at the source and at the destination.

[16] The mileages calculated for these shipments exclude the international segments (e.g., shipments from New York to Michigan through Canada do not include any mileages for Canada).

mapping given in Table 1, $A_i(j) = \frac{V_i(j)}{P_i L_i(j)}$ is calculated for all i, j as a measure of technology, where $V_i(j)$ is the industry and state specific value added of the relevant NAICS industry obtained from U.S. Census Bureau in 2002, P_i is the cost of living index for state i borrowed from Berry et al. (2003) for the year 2002, and $L_i(j)$ is industry and state specific hours of labor supplied by the production workers of the relevant NAICS industry obtained from U.S. Census Bureau in 2002.[17] It is important to note that the level of technology already includes a measure of wages through the cost of living index after assuming that real wages (rather than nominal wages) are equalized across regions. In other words, although the nominal wages are equalized across regions in the model to have more trackable framework, the real wages are equalized in the empirical analysis, because, as is standard in the literature, the labor respond to real wages rather than nominal wages in practice.

For distance measures, great circle distances between bilateral states are calculated. When calculating latitude and longitude of each state, the weighted average of latitudes and longitudes of the cities in that state are taken, where the weights are determined according to the production level of those cities. The production level in each city is measured by the real gross domestic product values obtained from Bureau of Economic Analysis (BEA) for 2002. By using these weights, more relevant spatial locations are obtained for measuring the potential interactions across states. Although an average distance measure is provided for each *observed* shipment in CFS, the benchmark analysis of this paper uses great circle distances, because the average distance measures in CFS are available only for realized trade observations. Since zero (trade) observations (i.e., the observation of no trade) are also considered in this paper, a more comprehensive distance measure is needed to capture the effect of distance on the absence of trade. Nevertheless, for robustness, the estimation results obtained by great circle distances are compared with the results obtained by CFS distances in the sensitivity analysis #3 below.

4. Remarks and Estimation Methodology

A two-step estimation process is employed. First, the empirical power of the model is tested at the disaggregate level and estimates of elasticity of substitution across varieties of each good (i.e., $\eta(j)$'s), and good specific distance elasticities (i.e., $\delta(j)$'s) are obtained; these are used to obtain good specific price indices (i.e., $P_i(j)$'s) according to the model. Second, the empirical power of the model is tested at the aggregate level and the elasticity of substitution across goods (i.e., ε) is estimated.

4.1. Disaggregate Level Trade Estimation

In this subsection, the implications of Equation 2.11 are provided, and different log versions of it that are used for robustness are introduced. Although Equation 2.11 holds on average, it doesn't hold for each bilateral trade ratio. In empirical terms, following Santos Silva and Tenreyro (2006), and Henderson and Millimet (2008), to address the unobservable nature of bilateral trade ratios, it is assumed that there is an error term associated with each ratio, which implies that:

$$\frac{X_{r,a}(j)}{X_{r,b}(j)} = \frac{\theta_a}{\theta_b} \left(\frac{A_a(j)}{A_b(j)} \right)^{\eta(j)-1} \left(\frac{D_{r,b}}{D_{r,a}} \right)^{\delta(j)\eta(j)} + \mu_{r,a,b,j}$$

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

$$\frac{X_{r,a}(j)}{X_{r,b}(j)} = \frac{\theta_a}{\theta_b} \left(\frac{A_a(j)}{A_b(j)} \right)^{\eta(j)-1} \left(\frac{D_{r,b}}{D_{r,a}} \right)^{\delta(j)\eta(j)} \upsilon_{r,a,b,j} \tag{4.1}$$

where

$$\upsilon_{r,a,b,j} = 1 + \frac{\mu_{r,a,b,j}}{\frac{\theta_a}{\theta_b} \left(\frac{A_a(j)}{A_b(j)} \right)^{\eta(j)-1} \left(\frac{D_{r,b}}{D_{r,a}} \right)^{\delta(j)\eta(j)}} \tag{4.2}$$

and $E\left[\upsilon_{r,a,b,j} \Big| \frac{\theta_a}{\theta_b}, \frac{A_a(j)}{A_b(j)}, \frac{D_{r,b}}{D_{r,a}} \right] = 1$. Taking the log of both sides in Equation 4.1 results in the following log-linear expression for the bilateral disaggregate level trade *ratios*:

$$\log \left(\frac{X_{r,a}(j)}{X_{r,b}(j)} \right) = \log \left(\frac{\theta_a}{\theta_b} \right) + (\eta(j) - 1) \log \left(\frac{A_a(j)}{A_b(j)} \right) + \delta(j)\eta(j) \log \left(\frac{D_{r,b}}{D_{r,a}} \right) + \log (\upsilon_{r,a,b,j}) \tag{4.3}$$

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[17] Although value added is used for each industry to calculate technology levels, this should not be necessary the case in the presence of a better measure of technology. In other words, the claim in the text saying "There is no need for any income data *given* the technology levels" still holds. Although the state-level production functions typically include public and private capital, to be consistent with the model, technology is defined on the basis of value added by labor.

To obtain a consistent estimator of the slope parameters by the Ordinary Least Squares (OLS), it is assumed that $E\left[\log\left(\upsilon_{r,a,b,j}\right)\Big|\frac{\theta_a}{\theta_b},\frac{A_a(j)}{A_b(j)},\frac{D_{r,b}}{D_{r,a}}\right]$ does not depend on the regressors.[18] Because of Equation 4.2, this condition is met only if $\mu_{r,a,b,j}$ can be written as follows:

$$\mu_{r,a,b,j} = \frac{\theta_a}{\theta_b}\left(\frac{A_a(j)}{A_b(j)}\right)^{\eta(j)-1}\left(\frac{D_{r,b}}{D_{r,a}}\right)^{\delta(j)\eta(j)}\xi_{r,a,b,j}$$

where $\xi_{r,a,b,j}$ is a random variable statistically independent of the regressors. In such a case, $\upsilon_{r,a,b,j} = 1 + \xi_{r,a,b,j}$ and therefore is statistically independent of the regressors, implying that $E\left[\log\left(\upsilon_{r,a,b,j}\right)\Big|\frac{\theta_a}{\theta_b},\frac{A_a(j)}{A_b(j)},\frac{D_{r,b}}{D_{r,a}}\right]$ is a constant. Following Santos Silva and Tenreyro (2006), the assumption of $E\left[\log\left(\upsilon_{r,a,b,j}\right)\Big|\frac{\theta_a}{\theta_b},\frac{A_a(j)}{A_b(j)},\frac{D_{r,b}}{D_{r,a}}\right]$ not depending on the regressors is relaxed in Sensitivity Analysis #4, below, by considering the Poisson Pseudo-Maximum Likelihood (PPML) estimator.

In the estimation, *only one* OLS (or PPML) regression is employed for the pooled sample by including relevant dummy variables for $\frac{\theta_a}{\theta_b}$, $\eta(j)$ and $\delta(j)$ in Equation 4.3. Although $A_i(j)$'s are region and good specific technology levels in Equation 4.3, they don't necessarily capture all the source specific fixed effects. This is why source specific taste parameters (i.e., θ_i's) may play an important role in the estimation. For instance, in addition to the technology levels, source specific fixed effects *may* capture possible differences in source specific production markups, source specific production taxes, and so on. The validity of having both these fixed effects and technology levels at the same time are tested in Version B and Version G of the empirical estimation, below.[19]

According to Equation 4.3, the following remarks are implied:

Remark 1. *Both $\delta(j)$ and $\eta(j)$ can be identified in Equation 4.3 which is not the case in most gravity models (see Anderson and van Wincoop 2003; Hummels 1999, 2001; Wei 1996).*

P roof. The identification is realized via the technology levels which are usually ignored in gravity models. In particular, since both $(\eta(j)-1)$ and $\delta(j)\eta(j)$ can be estimated by Equation 4.3, one can identify both $\eta(j)$ and $\delta(j)$ while also calculating their standard errors by employing the Delta method. ∎

Remark 2. *All the variables in Equation 4.3 are exogenous, which leaves an applied researcher free from a possible endogeneity problem. Moreover, there is no need for income data given the exogenous technology levels.*

P roof. The proof follows through Equation 2.11.[20] ∎

Remark 3. *Assuming that overstatement of a distance is proportional to the distance itself, the model controls for such an issue (because of the use of calculated distance measures such as great circle distances) as mentioned by Hillberry and Hummels (2001).*

P roof. Assuming that overstatement of a distance is proportional to the distance itself, the distance ratio in Equation 4.3 is not affected at all. See sensitivity analysis #3 in Section 5 for details. ∎

Remark 4. *By construction, the model is capable of controlling for the effects of local (i.e., wholesale and retail) distribution costs, insurance costs or local taxes, each of which are possible topics for separate debates in the literature (see Anderson and van Wincoop 2004).*

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[18] 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, we don't have such a concern, because our log-linearized equation does have values below zero, by considering the (log) ratio of bilateral trade values.

[19] Multicollinearity is less of a problem in a cross-sectional analysis like ours that has a high sample size. The reasoning is that we run only one regression instead of good specific regressions; if we were running good specific regressions, then θ_i's and $A_i(j)$'s would have been perfectly correlated, because, in such a case, we would have good specific θ_i's. Moreover, the individual effects of technology and source specific taste parameters can both be assessed when there are sufficient number of observations of high technology regions with low fixed effects and low technology regions with high fixed effects. Besides, the theoretical consequences of multicollinearity is still a debate, because even if the multicollinearity is very high, the OLS estimators still remain to be the best linear unbiased estimators. The only possible problem arises due to having wide confidence intervals in the presence of multicollinearity. However, by having very low confidence intervals, our estimation results below are robust to a possible multicollinearity problem. See Achen (1982) and Gujarati (1995) for more details.

[20] If trade leads to technology transfer, than technology may be correlated with past trade levels. And, if there are unobservables omitted that are serially correlated, then technology will be endogenous. Nevertheless, these are not issues in our case, because we have a static rather than a dynamic analysis. Moreover, we have unobservable (source specific, destination specific and bilateral specific) fixed effects in our analysis.

P roof. To see this, consider Equation 2.1 by including such possible good specific proportional costs. For instance, say that there is a proportional (net) cost of $\varphi(j)$ for good j in region r. Then, it follows that:

$$C_{r,a}(j) = \theta_a \left(\frac{P_{r,a}(j)(1+\varphi(j))}{P_r(j)(1+\varphi(j))} \right)^{-\eta(j)} C_r(j)$$

and

$$C_{r,b}(j) = \theta_b \left(\frac{P_{r,b}(j)(1+\varphi(j))}{P_r(j)(1+\varphi(j))} \right)^{-\eta(j)} C_r(j)$$

The same logic applies for Equation 2.5, which together with the expressions above, implies exactly the same expression as in Equation 2.10. ∎

Remark 5. *By construction, the model is capable of controlling for the effects of intermediate input trade.*

P roof. Proof follows through the definition of $X_{r,k}(j) = \left(C_{r,k}^T(j) + G_{r,k}^T(j) \right) P_{k,k}^T(j)$ in Equation 2.10. ∎

Under certain assumptions, the model is also capable of controlling for the effects of international trade. In particular, it is reasonable to assume that the international trade partners of the U.S. share similar tastes with the states in which the customs are located. The justification of this assumption comes from the fact that, in CFS, international export (import) shipments are included, with the domestic destination (source) defined as the U.S. port, airport, or border crossing of exit from the U.S. Given this assumption, it follows that the estimated trade ratio given by Equation 4.3 is not affected at all by international trade, since the inclusion of international trade will be proportional in such a case.

By using the general form in Equation 4.3, for robustness, several restricted versions of it are considered along with its unrestricted version. These restrictions are not only important for econometric significance tests, but they are also important for economic intuition in terms of the contribution of each variable in Equation 4.3 to explain the interstate trade patterns. In particular, the following versions of Equation 4.3 are considered in the empirical analysis:

Version A) Unrestricted version of Equation 4.3 in which $\boldsymbol{\eta^A}$ (the vector consisting of $\eta(j)$'s), $\boldsymbol{\theta^A}$ (the vector consisting of $\frac{\theta_a}{\theta_b}$'s), and $\boldsymbol{\delta^A}$ (the vector consisting of $\delta(j)$'s) are estimated for all r, j, a and b. This is the benchmark equation through which $\frac{\theta_a}{\theta_b}$ values are used as fixed effects in the regression, $\eta(j)$'s are estimated, $\delta(j)\eta(j)$'s are estimated, and thus, estimates of $\delta(j)$ are obtained. The relative standard errors are then obtained through the use of the Delta method.

Version B) Restricted version of Equation 4.3 in which $\theta_i = \theta$ for all i, thus, in which $\boldsymbol{\eta^B}$ (the vector consisting of $\eta(j)$'s), and $\boldsymbol{\delta^B}$ (the vector consisting of $\delta(j)$'s) are estimated for all j. Recall that in the unrestricted version of Equation 4.3, θ_i values serve as source specific fixed effects in the regression analysis. When $\theta_a = \theta_b$, it follows that $\log\left(\frac{\theta_a}{\theta_b}\right) = 0$. Thus, the purpose of this restricted version is to evaluate whether or not there are source specific fixed effects. This is also important in terms of testing the assumption of source specific taste parameters in the CES consumption/intermediate input functions. The contribution of these fixed effects in explaining the interstate trade patterns can also be figured out by comparing the results of this version with the results of version A through a restriction test.

Version C) Restricted version of Equation 4.3 in which $\delta(j) = \delta$ and $\eta(j) = \eta$ for all j, and thus, in which η, δ and $\boldsymbol{\theta^C}$ (the vector consisting of $\frac{\theta_a}{\theta_b}$'s) are estimated for all r, a and b. The purpose of this restriction is to decide whether or not trade costs and elasticities of substitution across varieties are good specific. This restriction is important, because most of the gravity type studies ignore good specific variations that affect the accuracy of the estimation results. Together with Version H, this restriction is also used to figure out whether or not the trade costs are good specific.

Version D) Restricted version of Equation 4.3 in which $\theta_i = \theta$ for all i; and in which $\delta(j) = \delta$ and $\eta(j) = \eta$ for all j; thus, in which η and δ are estimated. This restriction is used to test whether or not there are source specific taste parameters when there are common trade costs and common elasticity of substitution across varieties for different goods.

Version E) Restricted version of Equation 4.3 in which $\frac{\theta_r}{\theta_b} = \theta_H$ and $\frac{\theta_a}{\theta_b} = 1$ for all $r, a(\neq r), b(\neq r)$; and in which $\delta(j) = \delta$ and $\eta(j) = \eta$ for all j, thus, in which θ_H, η and δ are estimated. Since the analysis is made

for a typical region r, $\frac{\theta_r}{\theta_b} = \theta_H$ and $\frac{\theta_a}{\theta_b} = 1$ together mean that the goods purchased within a region are different from the goods imported from other regions, i.e., the so-called *home-bias*. Together with $\delta(j) = \delta$ and $\eta(j) = \eta$, the main purpose of this restriction is to find whether or not there is any home-bias, even at the intranational level, when trade costs and elasticities of substitution across varieties are the same across goods.

Version F) Restricted version of Equation 4.3 in which $\frac{\theta_r}{\theta_b} = \theta_H$ and $\frac{\theta_a}{\theta_b} = 1$ for all r, $a(\neq r)$, $b(\neq r)$; thus, in which $\theta_H, \boldsymbol{\eta^F}$ (the vector consisting of $\eta(j)$'s) and $\boldsymbol{\delta^F}$ (the vector consisting of $\delta(j)$'s) are estimated for all j. This is the same as version E except that trade costs are now good specific. Thus, the main purpose of this restriction is to find whether or not there is any home-bias, even at intranational level, when elasticities of substitution across varieties, and trade costs are good specific.

Version G) Restricted version of Equation 4.3 in which $A_a(j) = A_b(j)$ for all j (which is equivalent, since we talk about the ratios, saying that $A_i(j) = A$ for all i and j); thus, in which $\boldsymbol{\eta^G}\boldsymbol{\delta^G}$ (the vector consisting of $\eta(j)\delta(j)$'s) and $\boldsymbol{\theta^G}$ (the vector consisting of $\frac{\theta_a}{\theta_b}$'s) are estimated. The purpose of this restriction is to evaluate whether the technology levels are region specific or country specific.

Version H) Restricted version of Equation 4.3 in which $\eta(j) = \eta$ for all j, thus, in which η, $\boldsymbol{\theta^A}$ (the vector consisting of $\frac{\theta_a}{\theta_b}$'s), and $\boldsymbol{\delta^A}$ (the vector consisting of $\delta(j)$'s) are estimated for all r, j, a and b. The purpose of this restriction is to decide whether or not the elasticity of substitution across varieties is good specific. This restriction is important, because most of the gravity type studies ignore good specific $\eta(j)$'s which affect the accuracy of the estimation results.

4.2. Aggregate Level Trade Estimation

This subsection introduces the methodology to estimate Equation 2.13 that is tested using bilateral trade data at the aggregate level and the estimation results of the disaggregate level trade estimation. Analogous to the disaggregate level trade equation, although Equation 2.13 holds on average, it doesn't hold for each bilateral trade ratio. Therefore, it is assumed that there is an error term associated with each ratio, which implies that:

$$\frac{X_r(j)}{X_r(k)} = \frac{\gamma_j}{\gamma_k}\left(\frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right)^{1-\varepsilon} + \mu_{r,j,k}$$

where $E\left[\mu_{r,j,k}\left|\frac{\gamma_j}{\gamma_k}, \frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right.\right] = 0$. This can be rewritten as:

$$\frac{X_r(j)}{X_r(k)} = \frac{\gamma_j}{\gamma_k}\left(\frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right)^{1-\varepsilon} \upsilon_{r,j,k} \qquad (4.4)$$

where

$$\upsilon_{r,j,k} = 1 + \frac{\mu_{r,j,k}}{\frac{\gamma_j}{\gamma_k}\left(\frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right)^{1-\varepsilon}} \qquad (4.5)$$

and $E\left[\upsilon_{r,j,k}\left|\frac{\gamma_j}{\gamma_k}, \frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right.\right] = 1$. Taking the log of both sides in Equation 4.4 results in the following log-linear expression for the bilateral disaggregate level trade *ratios*:

$$\log\left(\frac{X_r(j)}{X_r(k)}\right) = \log\left(\frac{\gamma_j}{\gamma_k}\right) + (1-\varepsilon)\log\left(\frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r\theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right) + \log(\upsilon_{r,j,k}) \qquad (4.6)$$

To obtain a consistent estimator of the slope parameters by the OLS, it is assumed that

$$E\left[\log\left(\upsilon_{r,j,k}\right)\middle|\frac{\gamma_j}{\gamma_k}, \frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right] \text{ does not depend on the regressors. Because of Equa-}$$

tion 4.5, this condition is met only if $\mu_{r,j,k}$ can be written as follows:

$$\mu_{r,j,k} = \frac{\gamma_j}{\gamma_k}\left(\frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right)^{1-\varepsilon} \xi_{r,j,k}$$

where $\xi_{r,j,k}$ is a random variable statistically independent of the regressors. In such a case, $\upsilon_{r,j,k} = 1 + \xi_{r,j,k}$ and

therefore is statistically independent of the regressors, implying that $E\left[\log\left(\upsilon_{r,j,k}\right)\middle|\frac{\gamma_j}{\gamma_k}, \frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right]$

is a constant. As in the disaggregate level analysis, for robustness, in addition to the OLS regression, the assump-

tion of $E\left[\log\left(\upsilon_{r,a,b,j}\right)\middle|\frac{\gamma_j}{\gamma_k}, \frac{\left(\frac{\eta(j)}{\eta(j)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(j)}(A_i(j))^{\eta(j)-1}\right)^{\frac{1}{1-\eta(j)}}}{\left(\frac{\eta(k)}{\eta(k)-1}\right)\left(\sum_i \beta_r \theta_i D_{r,i}^{\delta(k)}(A_i(k))^{\eta(k)-1}\right)^{\frac{1}{1-\eta(k)}}}\right]$ not depending on the regressors is relaxed by

considering a PPML regression in the empirical analysis.

In the estimation, *only one* OLS (or PPML) regression is employed for the pooled sample by including relevant dummy variables for each $\frac{\gamma_j}{\gamma_k}$ in Equation 4.6. After having the estimates for $\eta(j)$'s and $\delta(j)$'s coming from the disaggregate level estimation, there are data and parameters for everything in Equation 4.6 except for β_i's and θ_i's. In particular, β_i's cannot be estimated through the disaggregate level analysis, because they are cancelled out after considering trade ratios. Moreover, each and every θ_i cannot be uniquely identified in the disaggregate level analysis due to overidentification issues. Hence, the aggregate level analysis is restricted to a special case in which $\beta_i = \theta_i = 1$ for all i.

Although calculated $P_i(j)$'s are region and good specific price levels in Equation 4.6, they don't necessarily capture all the good specific fixed effects, especially the actual preferences of the individuals for specific goods. This is why good specific taste parameters (i.e., γ_i's) may play an important role in the estimation. Below, the validity of having both these fixed effects and price levels at the same time is also tested.

5. Empirical Results

The empirical results for disaggregate and aggregate level trade estimations are given in the following subsections. However, one more issue has to be taken care of : How should zero trade observations (i.e., the absence of trade of a particular good for a particular bilateral state pair) be included in the log-linear estimated equation? For the sensitivity of the analysis, three different approaches are employed: 1) assume that zero (trade) observations are equal to one U.S. dollar's worth; 2) assume that zero (trade) observations are equal to one U.S. cent's worth; 3) ignore the zero (trade) observations.[21] Although the last one will be biased toward low elasticities of substitution compared to the other two, it is worth presenting it for the sake of sensitivity. Moreover, the third approach is also used to compare the effects of using great circle distances and actual CFS distances, which is mentioned by Hillberry and Hummels (2001). The estimation based on the first approach will be presented as the Benchmark Case, and the estimation based on the others will be presented as the Sensitivity Analyses.

5.1. Disaggregate Level Trade Estimation Results

The disaggregate level trade estimation results for the benchmark case (i.e., the first approach in which zero trade observations are set equal to one U.S. dollar's worth) are given in Table 2. Table 2 distinguishes between different versions of the estimated equation. As described above, versions B,C,D,E, F, and H are all restricted versions of version A, and version G is a special case of version A. Thus, these restrictions can be tested, and it can be decided whether or not they are valid. The test results for these restrictions are given in Table 3. As is evident, all the restrictions are rejected according to F-test results. This suggests that Version A, which is obtained through the model, is selected among all of versions. This implies that:

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[21]Unfortunately, a tobit specificition cannot be employed to account for the zeros, because trade ratios rather than trade levels are considered. In particular, when there is a zero trade observation, then either the numerator or the denominator of the left hand side of Equation 4.3 (or both) is equal to zero. This would make the trade ratio equal to either zero or infinity (or indeterminate), and thus, employing a tobit specification would not be plausible in log terms.

- Source specific fixed effects are found to be significant in version B, which supports the assumption of source specific taste parameters in the utility function.

- Trade costs are found to be good specific in version C, which supports the assumption of good specific trade costs.

- Production technology for each good is found to be region specific in version G, which further supports the model.

- Elasticity of substitution across varieties is found to be good specific in version H, which supports the disaggregate level model.

As is evident by Version A in Table 2, the elasticity of substitution across regions is estimated as 5.24 on average.[22] Since the intranational studies within the U.S. such as Wolf (2000), Hillberry and Hummels (2001), and Millimet and Thomas (2007) use gravity equations, they cannot estimate for the elasticity of substitution and the elasticity of distance at the same time. So, the results in this paper are compared with the results in empirical international trade literature. It is found that the estimates of this paper for the elasticity of substitution are lower on average. 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 (1993) 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. This difference may be due to the distinction between intranational and international data sets as well as the ignored factors in the literature such as local distribution costs, insurance costs, local taxes and intermediate input trade. Since the model of this paper controls for all of these factors, it can be claimed that we have more accurate results intranationally. Someone may claim that the difference between the estimates of this paper and the estimates in the literature may also be due to the inclusion of zero trade observations; however, as it will be shown in the sensitivity analyses below, the difference gets higher when zero trade observations are ignored, which is what the studies mentioned above actually do.

According to Version A in Table 2, the distance elasticity is estimated as 0.60 on average. This average value is higher than the distance elasticity estimates found by the literature, which are about 0.3 (see Hummels, 2001; Limao and Venables, 2001; Anderson and van Wincoop, 2004). This difference is most probably again due to using different frameworks or data sets, as well as due to the inclusion of zero (trade) observations into the analysis. The latter possibility will be tested in the sensitivity analysis below. Another possible explanation for the difference between the distance elasticity estimates of this paper and the ones in the literature may be the mode of transportation for interstate trade. In particular, it may well be the case that the interstate trade is done by air through couriers like UPS, FedEX, and so forth, while the international trade is done in transportation modes different from those. This possibility will also be considered by employing different distance measures in the sensitivity analysis below. Another reason may be the usual assumption of iceberg transport costs in the literature. As can be shown, if such an assumption is used instead of having a transportation sector, the distance elasticities would have had lower estimates.[23] However, since the data set of CFS provides only the income received by the exporter firms (and excludes transportation income), it is distinguished between the exporter income and the transporter income, which is against the iceberg cost assumption.

Although version A (implied by the model) is selected among all estimated versions by the restriction tests, one can still have inference from other versions. Note that versions E and F represent the cases by which we can analyze whether or not there is a home-bias. Again according to Table 2, the values for θ_H are positive and significant, which, according to the definitions of versions E and F, suggest that there is a home-bias across the states of the U.S. This bias is estimated as 5.73 by Equation E and 2.25 by Equation F. However, since Equation E is a restricted version of Equation F, one can further test this restriction. It is found that the restriction is rejected, which means that a home-bias of 2.25 is more plausible compared to 5.73. In particular, a typical state has a taste parameter θ for locally produced goods about 2.25 times more than imported goods. This number is very close to the intranational home-bias estimated by Hillberry and Hummels (2003) which is $exp(0.99) = 2.69$. Therefore, although the literature overestimates the elasticity of substitution measures and underestimates the elasticity of

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[22] The individual estimated are available upon request. Also note that the estimates are highly significant. Moulton (1986) suggests that one should adjust the standard errors for OLS for the fact that the errors are correlated within the groups because of the common group effect. In this context, for robustness, we have also considered Moulton standard errors, and the (t-test) results are almost the same. These results are also available upon request. See Moulton (1986) and Donald and Lang (2007) for the details of Moulton standard errors.

[23] It can be shown easily that the average $\delta(j)$ estimate given in Table 1 (i.e.,0.59) would be replaced by 0.43 under the iceberg cost assumption.

distance measures with respect to our results, the measures of home-bias seem to be similar. One explanation is due to the interaction between the two elasticity measures in Equation 4.3. In particular, if two elasticity measures operate in opposite signs (i.e., if one is overestimated and the other is underestimated), then the results for the fixed effects captured by θ values are not affected too much since two estimation errors cancel each other out to some degree.

Finally, the high adjusted R^2 value of 0.42 for Equation A also supports our model. Although version A (implied by the model) is selected among all estimated versions by our significance tests, the contribution of each variable in Equation 4.3 can still be compared, in terms of explaining interstate trade patterns, by considering the adjusted R^2 values of each version. In particular, the highest difference of adjusted R^2 values takes place between versions A and D&E, which means that source specific fixed effects and good specific trade costs together play an important role in the estimations. The second highest difference of adjusted R^2 values takes place between versions A and B&F, which means that source specific fixed effects are significant individually. The third highest difference of adjusted R^2 values takes place between versions A and C, which means that good specific trade costs are also significant individually. Finally, the lowest difference of adjusted R^2 values takes place between versions A, G and H, which means that good and region specific technology parameters and elasticities of substitution across goods, besides the source specific fixed effects, play a lesser role compared to other parameters, which is reasonable since the empirical analysis is achieved within a highly integrated economy, the U.S.

5.1.1. Sensitivity Analyses

In order to support test the validity of the empirical results, four sensitivity analyses are employed in this section. The first two are related to zero (trade) observations, the third one is related to distance measures, and the last one is related to a possible biasedness of the OLS estimator in log-linearized models.

Sensitivity Analysis #1 We start the sensitivity analysis by setting zero (trade) observations equal to one U.S. cent's worth. In such a case, the estimation results in Table 2 are replaced by the ones in Table 4. Note that the restrictions of versions B, C, D, E, F, G, and H can again be tested with respect to version A. The test results for these restrictions are given in Table 5. As is evident, all the restrictions are again rejected according to our F-test results. This suggests that version A is again selected among all equations. The high adjusted R^2 value of 0.40 for Equation A again supports the model.

As is evident by Version A in Table 4, the elasticity of substitution is estimated as 6.27 on average. Although this average value is slightly higher than the ones in our benchmark case, they are still lower than the estimates in the literature on average.[24]

The distance elasticity is estimated as 0.61 on average, which is very close to the initial estimate in Table 2, yet higher than the ones in the literature.

Again according to Table 4, the values for θ_H are positive and significant, which according to the definitions of versions E and F, suggest that there is a home-bias across the states of the U.S. After a restriction analysis between versions E and F, the restriction in E is rejected; thus, a typical state has a taste parameter θ for locally produced goods about 1.95 times more than imported goods. This number is close to the initial estimate of 2.25 in the benchmark case.

Sensitivity Analysis #2 For the second sensitivity analysis, the zero (trade) observations are ignored. In such a case, the estimation results in Table 2 are replaced by the ones in Table 6. The restrictions of versions B, C, D, E, F, G, and H are again tested with respect to version A. The test results for these restrictions are given in Table 7. As is evident, all the restrictions are again rejected according to F-test results. This suggests that version A is again selected among all equations. The high adjusted R^2 value of 0.60 for Equation A again supports the model.

This time, according to Version A in Table 6, the elasticity of substitution is estimated as 2.70 on average. This average value is very low compared to the studies mentioned above even though they also ignore zero trade observations (as in this subsection). We had given possible explanations for this difference above, so we won't repeat them here.

The distance elasticity is estimated as 0.37 on average. Although this average value is closer to the distance elasticity estimates in the literature (that we mentioned above, which are about 0.3), it is still relatively higher. Thus, the difference between the first two estimates of distance elasticities (i.e., the estimates in the benchmark case and the first sensitivity analysis) and the estimates in the literature can, to some degree, be explained by the

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[24]Even if we set zero trade observations equal to 0.01 U.S. cent worth, the elasticity of substitution is estimated as 6.50 on average.

inclusion of zero (trade) observations in the first two estimations. Nevertheless, the difference doesn't disappear completely.

According to Table 6, the values for θ_H are again positive and significant, which according to the definitions for Equations E and F, suggest that there is a home-bias across the states of the U.S. In particular, a typical state has a taste parameter θ for locally produced goods about 1.93 times more than imported goods after testing for the restriction between Equations E and F and rejecting it. This number is lower compared to our initial estimates and the estimates of Hillberry and Hummels (2003).

Sensitivity Analysis #3 Until now, great circle distances have been used in the estimations, because average distance measures are not provided by CFS for zero (trade) observations. However, as is shown by Hillberry and Hummels (2001), using great circle distances, instead of actual distances provided by CFS, may overstate the distance measure as in Wolf (2000). In one of the remarks, we had claimed that we already control for this issue by taking the ratio of imports as the dependent variable. Moreover, the coefficient of correlation between the great circle distances and actual distances provided by CFS is calculated as 0.98, after ignoring zero trade observations. Nevertheless, as the third sensitivity analysis, the sensitivity analysis #2 is repeated, this time using the average distance measure provided by CFS instead of the great circle distance measure that has been used until now. In this way, the effects of great circle distances and the CFS distances can be compared.

When CFS distances are used, the estimation results of sensitivity analysis #2 given in Table 6 are replaced by the ones in Table 8. The restrictions of versions B, C, D, E, F, G, and H are again tested with respect to version A. The test results for these restrictions are given in Table 9. As is evident, all the restrictions are again rejected according to F-test results. This suggests that version A is again selected among all equations. The high adjusted R^2 value of 0.60 for Equation A again supports the model.

As is evident by Version A in Table 8, the elasticity of substitution is estimated as 2.74 on average. The distance elasticity is estimated as 0.38 on average. All of these estimates are very close to the ones presented for Sensitivity Analysis #2.

According to Table 8, the values for θ_H are again positive and significant, which, according to the definitions of Equations E and F, suggest that there is a home-bias across the states of the U.S. In particular, a typical state has a taste parameter θ for locally produced goods about 2.03 times more than imported goods after testing for the restriction between Equations E and F, and rejecting it. Although this number is close to our initial estimates, it is slightly higher compared to Table 6.

Overall, the numbers in Table 6 and Table 8 are not significantly different from each other. This result supports the claim that overstating distances mentioned by Hillberry and Hummels (2001) is already controlled for in this paper.

Sensitivity Analysis #4 For the last sensitivity analysis, the benchmark case and the first three sensitivity analyses are repeated by using 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 4.3 can be written as follows:

$$\frac{X_{r,a}(j)}{X_{r,b}(j)} = \exp\left(\log\left(\frac{\theta_a}{\theta_b}\right) + (\eta(j) - 1)\log\left(\frac{A_a(j)}{A_b(j)}\right) + \delta(j)\eta(j)\log\left(\frac{D_{r,b}}{D_{r,a}}\right)\right)\upsilon_{r,a,b,j} \qquad (5.1)$$

Assuming $E[\upsilon_{r,a,b,j}|\frac{\theta_a}{\theta_b}, \frac{A_a(j)}{A_b(j)}, \frac{D_{r,b}}{D_{r,a}}] = 1$, then Equation 5.1 may be estimated consistently using the Poisson Pseudo-Maximum Likelihood (PPML) estimator (see Santos Silva and Tenreyro, 2006). Since Version A has been chosen among all versions earlier, we repeat our analysis only for Version A here. The results are given in Table 10.

As is evident, the (average) elasticity of substitution across varieties η ranges between 2.17 and 2.63, and the (average) elasticity of distance δ ranges between 0.30 and 0.59, which are both consistent with our earlier claim that our η estimates are lower than and our δ estimates are higher than the ones in the international trade literature.

5.2. Aggregate Level Trade Estimation Results

The aggregate level trade estimation results are given in Table 11. As in the disaggregate level analysis, four different approaches with two different estimation methods, OLS and PPML are considered. As is evident, the elasticity of substitution across goods is estimated as 1.38 by OLS (respectively, 2.19 by PPML) in the benchmark case, which is the one that sets zero trade observations equal to one U.S. dollar's worth. When zero trade observations are set equal to one U.S. cent's worth, the elasticity of substitution across goods is estimated as 1.27 by OLS (respectively,

2.19 by PPML). When zero trade observations are ignored, it is estimated as 1.95 by OLS (respectively, 2.44 by PPML). Finally, when CFS distance measures are used instead of great circle distances, it is estimated as 1.92 by OLS (respectively, 2.97 by PPML).

Although the estimates of ε are lower than the elasticity of substitution across varieties estimates (i.e., $\eta(j)$'s), as expected, according to OLS estimator, they are very close to each other according to PPML estimator. This result is consistent with the view that when goods are aggregated, the elasticity of substitution across them decreases. Nevertheless, these numbers are significantly lower than the estimates in the literature that were discussed above. As in the disaggregate level analysis, we claim that this difference may be due to distinction between intranational and international data sets as well as the ignored factors in the literature such as local distribution costs, insurance costs, local taxes and intermediate input trade. Since the model of this paper controls for all of these factors, we claim that we have more accurate results intranationally. The results are further supported by several sensitivity analyses with high explanatory powers.[25]

6. Conclusions

This paper has introduced a partial equilibrium model to find motivations for bilateral trade ratios across regions. It is shown that a region imports more goods from the higher technology regions and fewer goods from the more distant regions, subject to an elasticity of substitution across varieties. Moreover, a region imports more of a good, of which price is lower, subject to an elasticity of substitution across goods. When bilateral trade is estimated in ratio form (rather than in levels), the model of this paper has several empirical and analytical benefits compared to the gravity models, which are explained in details in the text. Thanks to the disaggregate (state) level data set combined from the Commodity Flow Survey and the U.S. Census Bureau, it is found that the simple model of this paper is capable of explaining the interstate trade patterns within the U.S. It is also shown that the elasticity of substitution measures are overestimated in the literature, while the elasticity of distance measures (thus, trade costs) are underestimated in the literature relative to the estimates of this paper.

It has been also shown that source specific fixed effects and good specific taste parameters are important for bilateral trade patterns, which are usually ignored in the literature. Moreover, elasticities of substitution across varieties and trade costs are good specific, which is not a considered fact in most of the aggregate level gravity type studies. Besides, production technology for each good is found to be region specific rather than country specific. Several sensitivity analyses support these results.

The best strategy for possible future research would be to extend the model of this paper toward explaining international trade patterns. Such an analysis would be more convenient with a general equilibrium framework, although a partial equilibrium framework was sufficient for this paper.

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[25]We have also tested different restricted versions of Equation 4.6, such as common γ's or common $P_i(j)$'s, in our aggregate level analysis. We find that none of the restrictions are valid, and therefore Equation 4.6 is selected among all versions. These restriction test results are available upon request.

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Table 1 - Crosswalk Between NAICS and SCTG

SCTG	NAICS	SCTG	NAICS	SCTG	NAICS
2	$311-312^*$	17	324	31	327
3	$311-312^*$	18	324	32	$331-324^*$
4	$311-312^*$	19	$324-325^*$	33	332
5	$311-312^*$	20	325	34	333
6	$311-312^*$	21	325	35	$334-335^*$
7	$311-312^*$	22	325	36	336
8	$311-312^*$	23	325	37	336
9	$311-312^*$	24	326	38	334
11	212^{**}	26	321	39	337
12	212^{**}	27	322	40	339
13	212^{**}	28	322	41	$313-331^*$
14	212^{**}	29	323	43	MIX OF ALL
15	212^{**}	30	313		

Notes: The source is National Transportation Library of the Bureau of Transportation Statistics. * means that an average of the relevant NAICS industries has been used to obtain technology levels. ** means that there is no corresponding production data for that specific NAICS industry in the U.S. Census Bureau data set; thus, we assume that the technology levels are the same across states for those industries. Finally, SCTG 43 corresponds to mixed freight for which an average of all other NAICS industries in the table are used to obtain technology levels.

Table 2 - OLS Estimation Results

	Equation							
	A	B	C	D	E	F	G	H
η	[5.24]	[1.16]	5.31	1.12	1.08	[1.13]	–	5.24
	[(0.08)]	[(0.16)]	(0.06)	(0.03)	(0.03)	[(0.17)]	–	(0.03)
δ	[0.60]	[2.76]	0.59	2.85	2.87	[2.78]	–	[0.60]
	[(0.03)]	[(0.13)]	(0.01)	(0.02)	(0.03)	[(0.14)]	–	[(0.29)]
θ	$\boldsymbol{\theta^A}$	–	$\boldsymbol{\theta^C}$	–	5.73	2.25	$\boldsymbol{\theta^G}$	$\boldsymbol{\theta^H}$
	$(\cdot)$	–	$(\cdot)$	–	(0.29)	(0.22)	$(\cdot)$	$(\cdot)$
$\delta\eta$	–	–	–	–	–	–	$\boldsymbol{\eta\delta^G}$	–
	–	–	–	–	–	–	$(\cdot)$	–
R-bar sqd.	0.42	0.31	0.37	0.26	0.26	0.31	0.41	0.41

Notes: The standard errors calculated by Delta method are in parenthesis. The sample size for all estimations is 47,819 which is found after considering the independent observations (ratios) and after ignoring the missing observations. The average of the estimated vectors of η^A and δ^A are given in brackets. The estimated vectors of θ^A, θ^C, θ^G and θ^H (all having a size of 505) are omitted to save space. For equations E and F, θ corresponds to θ_H. For Equations A-F, the estimates for $\delta\eta$ are omitted since the estimates for δ and η are already given separately.

Table 3 - Restriction Test Results

	Equation						
	B	C	D	E	F	G	H
F-test	18.74	48.91	23.97	23.86	18.74	7.10	7.29
d.f. 1	505	74	579	578	504	38	37
d.f. 2	$47,743$	$47,312$	$47,817$	$47,816$	$47,742$	$47,276$	$47,275$
p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: The null hypothesis is that the restrictions are valid.

Table 4 - OLS Estimation Results for Sensitivity Analysis #1

| | Equation | | | | | | | |
	A	B	C	D	E	F	G	H
η	[6.27]	[1.19]	6.37	1.15	1.11	[1.17]	–	6.26
	[(0.07)]	[(0.18)]	(0.06)	(0.03)	(0.03)	[(0.20)]	–	(0.03)
δ	[0.61]	[3.31]	0.61	3.41	3.46	[3.34]	–	[0.62]
	[(0.03)]	[(0.17)]	(0.01)	(0.03)	(0.03)	[(0.17)]	–	[(0.30)]
θ	$\boldsymbol{\theta^A}$	–	$\boldsymbol{\theta^C}$	–	6.00	1.95	$\boldsymbol{\theta^G}$	$\boldsymbol{\theta^H}$
	$(\cdot)$	–	$(\cdot)$	–	(0.26)	(0.26)	$(\cdot)$	$(\cdot)$
$\delta\eta$	–	–	–	–	–	–	$\boldsymbol{\eta\delta^G}$	–
	–	–	–	–	–	–	$(\cdot)$	–
R-bar sqd.	0.40	0.30	0.36	0.25	0.25	0.30	0.39	0.39

Notes: The standard errors calculated by Delta method are in parenthesis. The sample size for all estimations is 47,819 which is found after considering the independent observations (ratios) and after ignoring the missing observations. The average of the estimated vectors of η^A and δ^A are given in brackets. The estimated vectors of θ^A, θ^C, θ^G and θ^H (all having a size of 505) are omitted to save space. For equations E and F, θ corresponds to θ_H. For Equations A-F, the estimates for $\delta\eta$ are omitted since the estimates for δ and η are already given separately.

Table 5 - Restriction Test Results for Sensitivity Analysis #1

	Equation						
	B	C	D	E	F	G	H
F-test	18.03	46.96	23.06	23.00	18.05	6.91	7.09
d.f. 1	505	74	579	578	504	38	37
d.f. 2	$47,743$	$47,312$	$47,817$	$47,816$	$47,742$	$47,276$	$47,275$
p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: The null hypothesis is that the restrictions are valid.

Table 6 - OLS Estimation Results for Sensitivity Analysis #2

	Equation							
	A	B	C	D	E	F	G	H
η	[2.70]	[1.06]	2.63	1.05	1.01	[0.98]	–	2.68
	[(0.09)]	[(0.18)]	(0.06)	(0.02)	(0.02)	[(0.20)]	–	(0.04)
δ	[0.37]	[0.92]	0.38	0.86	0.83	[0.93]	–	[0.37]
	[(0.03)]	[(0.02)]	(0.01)	(0.01)	(0.01)	[(0.12)]	–	[(0.18)]
θ	$\boldsymbol{\theta^A}$	–	$\boldsymbol{\theta^C}$	–	2.03	1.93	$\boldsymbol{\theta^G}$	$\boldsymbol{\theta^H}$
	$(\cdot)$	–	$(\cdot)$	–	(0.08)	(0.15)	$(\cdot)$	$(\cdot)$
$\delta\eta$	–	–	–	–	–	–	$\boldsymbol{\eta\delta^G}$	–
	–	–	–	–	–	–	$(\cdot)$	–
R-bar sqd.	0.60	0.33	0.58	0.32	0.32	0.33	0.59	0.59

Notes: The standard errors calculated by Delta method are in parenthesis. The sample size for all estimations is 12,581 which is found after considering the independent observations (ratios) and after ignoring the missing observations together with zero observations. The average of the estimated vectors of η^A and δ^A are given in brackets. The estimated vectors of θ^A, θ^C, θ^G and θ^H (all having a size of 709) are omitted to save space. For equations E and F, θ corresponds to θ_H. For Equations A-F, the estimates for $\delta\eta$ are omitted since the estimates for δ and η are already given separately.

Table 7 - Restriction Test Results for Sensitivity Analysis #2

	Equation						
	B	C	D	E	F	G	H
F-test	14.56	7.40	13.89	13.70	14.40	4.61	4.72
d.f. 1	701	74	775	774	700	38	37
d.f. 2	$12,740$	$12,113$	$12,814$	$12,813$	$12,739$	$12,077$	$12,076$
p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: The null hypothesis is that the restrictions are valid.

Table 8 - OLS Estimation Results for Sensitivity Analysis #3

	Equation							
	A	B	C	D	E	F	G	H
η	[2.74]	[1.08]	2.66	1.06	1.01	[1.01]	–	2.70
	[(0.09)]	[(0.18)]	(0.06)	(0.02)	(0.01)	[(0.20)]	–	0.04
δ	[0.38]	[0.92]	0.38	0.86	0.83	[0.92]	–	[0.38]
	[(0.04)]	[(0.12)]	(0.01)	(0.01)	(0.01)	[(0.13)]	–	[(0.18)]
θ	$\boldsymbol{\theta^A}$	–	$\boldsymbol{\theta^C}$	–	2.16	2.03	$\boldsymbol{\theta^G}$	$\boldsymbol{\theta^H}$
	$(\cdot)$	–	$(\cdot)$	–	(0.09)	(0.19)	$(\cdot)$	$(\cdot)$
$\delta\eta$	–	–	–	–	–	–	$\boldsymbol{\eta\delta^G}$	–
	–	–	–	–	–	–	$(\cdot)$	–
R-bar sqd.	0.60	0.32	0.59	0.31	0.32	0.33	0.59	0.59

Notes: The standard errors calculated by Delta method are in parenthesis. The sample size for all estimations is 12,581 which is found after considering the independent observations (ratios) and after ignoring the missing observations together with zero observations. The average of the estimated vectors of η^A and δ^A are given in brackets. The estimated vectors of θ^A, θ^C, θ^G and θ^H (all having a size of 709) are omitted to save space. For equations E and F, θ corresponds to θ_H. For Equations A-F, the estimates for $\delta\eta$ are omitted since the estimates for δ and η are already given separately.

Table 9 - Restriction Test Results for Sensitivity Analysis #3

	Equation						
	B	C	D	E	F	G	H
F-test	14.36	6.88	13.71	13.51	14.20	4.40	4.53
d.f. 1	709	74	783	782	708	38	37
d.f. 2	$12,505$	$11,870$	$12,579$	$12,578$	$12,504$	$11,834$	$11,833$
p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: The null hypothesis is that the restrictions are valid.

Table 10 - PPML Estimation Results

	$\eta^{\mathbf{A}}$	$\delta^{\mathbf{A}}$	R-bar sqd.
Benchmark Case	2.17	0.59	0.54
	(0.01)	(0.01)	
Sensitivity Analysis #1	2.17	0.59	0.54
	(0.01)	(0.01)	
Sensitivity Analysis #2	2.63	0.30	0.83
	(0.04)	(0.01)	
Sensitivity Analysis #3	2.54	0.34	0.84
	(0.04)	(0.01)	

Notes: The standard errors calculated by Delta method are in parenthesis. For each case, the sample size is the same as in the earlier tables. The average of the estimated vectors of $\eta^{\mathbf{A}}$ and $\delta^{\mathbf{A}}$ are presented.

Table 11 - Estimation Results for Elasticity of Substitution Across Goods (ε)

	ε	R-bar sqd.
Benchmark Case (OLS)	1.38	0.68
	(0.14)	
Sensitivity Analysis #1 (OLS)	1.27	0.68
	(0.13)	
Sensitivity Analysis #2 (OLS)	1.95	0.77
	(0.14)	
Sensitivity Analysis #3 (OLS)	1.92	0.77
	(0.14)	
Benchmark Case (PPML)	2.19	0.13
	(0.01)	
Sensitivity Analysis #1 (PPML)	2.19	0.13
	(0.01)	
Sensitivity Analysis #2 (PPML)	2.44	0.08
	(0.01)	
Sensitivity Analysis #3 (PPML)	2.97	0.07
	(0.02)	

Notes: The standard errors are in parenthesis The sample size for all estimations is 1,319 which is found after considering the independent observations (ratios) and after ignoring the missing observations.