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Local Costs of Distribution, International Trade Costs and Micro Evidence on the Law of One Price

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Abstract: Using retail price survey data, I investigate whether international goods' market segmentation implied by dispersion in goods' prices is consistent with market segmentation implied by observed trade flows. A Ricardian trade model, with heterogeneous and asymmetric bilateral trade costs, accounts for 85 percent of the average price dispersion and 21 percent of the across good variation in it. Adding good-specific distribution costs reproduces 96.5 percent of the average and 32 percent of the variation in price dispersion. Allowing for good-specific trade costs enables the model to match the average perfectly and explain 48 percent of the variation. While trade and distribution costs explain price dispersion of an average retail good, they account for only half of the across good variation.

JEL Codes: F11, F15

Keywords: Trade, international trade costs, distribution costs, law of one price, price dispersion

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1 Introduction

Two empirical approaches have commonly been used in recent studies to investigate the degree of international goods market segmentation. One approach assesses the role of distance and borders - "geography" - in determining the volume of bilateral trade flows[1]. The other attempts to measure the role of geography and specific features of the market structure in determining the degree of price dispersion[2]. In this paper, I investigate whether a model that is consistent with the degree of goods market segmentation implied by observed cross-border trade flows can generate the cross-border price dispersion observed in the data.

In frictionless international markets, arms' length trade in goods by consumers will arbitrage away price differentials across countries, such that the absolute law of one price (LOOP) holds. There are two commonly cited sources of goods market segmentation that give rise to LOOP deviations; first, international trade costs or barriers to trade - both observed and unobserved and, second, the prevalence of non-traded input costs of distributing and retailing goods in local markets. My objective, in this paper, is to explore whether a multi-country Ricardian trade model, in which trade costs are estimated to be consistent with bilateral trade flows and local costs of distribution are calibrated to match distribution margins, can quantitatively account for the distribution of observed, good-by-good LOOP deviations.

How large are the deviations from LOOP? Most empirical work focusing on the measurement of deviations from LOOP are limited by the use of price index data, or of prices of a very narrow set of individual goods. Due to these data limitations, very little has been known about the magnitude of absolute deviations from the LOOP for a broad cross section of goods, and much of the empirical evidence concerns the volatility and persistence of changes in relative prices, although the first-order restrictions from theory are on absolute LOOP deviations. Crucini, Telmer and Zachariadis (2005), however, use local-currency retail prices on a broad cross-section of goods across 13 European Union (EU) countries to study

[1]Krugman (1991), McCallum (1995), Eaton and Kortum (2002), and Alvarez and Lucas (2007).

[2]Knetter (1993), Campa and Wolf (1997), Burstein, Neves and Rebelo (2003), and Atkeson and Burstein (2008).

good-by-good deviations from LOOP for the years 1975, 1980, 1985, and 1990[3]. They define the deviation from LOOP for good x in country i as the deviation of the logarithm of the common currency price of good x in country i from its cross-country geometric average price. The standard deviation of these LOOP deviations across countries is the "cross-country dispersion of LOOP deviations" in the price of good x, or "good-by-good price dispersion". They find that the degree of price dispersion varies significantly across goods.

In this paper, I attempt to account for the empirical values of two moments of the distribution of good-by-good price dispersion found by Crucini et al. (2005): (i) the average good-by-good price dispersion, which is about 28 percent, and (ii) the variation in good-by-good price dispersion across goods, which ranges from a minimum of 2 percent to a maximum of 83 percent. The first moment provides a measure of market segmentation for a broad set of goods. The second moment shows that, within this broad set of goods, there are some goods for which markets are not segmented at all, and some others for which the degree of market segmentation is much higher than that reflected by the first moment. I ask whether a structural model which allows for country and good specific geography, and nontraded inputs, can quantitatively account for the average degree of price dispersion and for the good by good heterogeneity in price dispersion?

Anderson and Wincoop (2004) emphasize the need for structural modeling of the link between relative prices and trade costs, and the need for a structural model to study relative price deviations is similarly highlighted by Gorodnichenko and Tesar (2009) in the context of measuring border effects[4]. Although some recent work has used structural models to study the effect of bilateral trade costs on the time-series behavior of bilateral relative prices - Atkeson and Burstein (2008), Bergin and Glick (2006), Ghironi and Melitz (2005), and Betts and Kehoe (2001) for example - the ability of a model of geography to contribute to an account of cross-sectional price dispersion has not been formally investigated. The first question that I address in this paper is, Can a multi-country Ricardian model with good-

[3]Rogers (2001), Engel and Rogers (2004), Crucini and Shintani (2008), and Engel, Rogers and Wang (2005) also use broad cross-sectional dataset of retail prices. But, none of these studies look at absolute deviations from LOOP.

[4]The authors find that in the absence of a structural model it is impossible to separate the border effect from the effect of trading with a country with different distribution of prices.

specific heterogeneity in productivity, in which cross country heterogeneous trade costs are carefully calibrated to match bilateral trade volumes, account for the average dispersion - and the variation in dispersion - of LOOP deviations?

Ethier (1979) and Sanyal and Jones (1982) argue that much of international trade takes place in intermediate goods, and all final goods sold to the consumers are non-traded goods because they use non-traded inputs such as distribution services. Again, the literature has largely investigated the role of distribution services in explaining the time series properties of international relative prices, and not the cross-sectional properties. Burstein et al. (2003) and Crucini and Shintani (2008) study the role of distribution services in understanding the movements of real exchange rate (RER), while Corsetti and Dedola (2005) and Goldberg and Campa (Forthcoming) study incomplete exchange rate pass-through in the presence of a distribution sector. Notably, Crucini et al. (2005), using a reduced form regression analysis, find that a significant portion of the heterogeneity in good-by-good price dispersion is indeed attributable to heterogeneity in the tradability of inputs. However, the functional form restrictions they impose in their regressions are not supported by the data, which they admit is a limitation of their analysis. The second question that I address is, To what extent can a version of the multi-country Ricardian model, modified to include a distribution sector in which costs of distribution are carefully calibrated to data on observed distribution margins, quantitatively account for the observed dispersion in LOOP deviations?

In order to address these two questions, I develop a general equilibrium version of the Eaton and Kortum (2002) trade model. The baseline variant of the model is attributable to Alvarez and Lucas (2007), except that I allow trade costs to be asymmetric and heterogeneous across trading partners. In the model, countries trade a continuum of goods, differentiated in productivity, which are produced using labor, capital and an intermediate input. To quantify the role of local distribution costs, I extend this baseline model by embedding a distribution sector, and explicitly model retail goods as products of the individual traded goods and non-traded distribution services. The units of distribution services that are needed to deliver one unit of a retail good to the consumer vary across goods. Furthermore, some countries are more efficient in delivering goods to the consumers than other countries. Thus the extended model allows for both good-specific, and country-specific, heterogeneity in distribution costs.

This paper is closest in spirit to Crucini and Yilmazkuday (2009), who develop a model of international cities to account for intra as well inter-national behavior of relative prices. They take a narrower measure of trade costs, by measuring them only in terms of distance between cities; by contrast, I proxy trade costs by distance, language, border and membership of free trade regions. More importantly, I estimate trade costs and solve the model by matching the trade volumes observed in the data. This allows me to assess whether a model that is consistent with observed trade flows can account for observed dispersion in prices.

I find that the standard multi-country Ricardian trade model, featuring bilateral, heterogeneous and asymmetric trade costs, does a good job of matching the average good-by-good price dispersion, but it fails to generate the variation in good-by-good price dispersion observed in the data. It can explain 85 percent of average price dispersion, but only 21 percent of the variation in price dispersion. Accounting for differences in costs of distribution across goods and across countries improves the model's performance in matching the data. This augmented model can generate 96.5 percent of the average price dispersion and 32 percent of the variation in price dispersion. The degree of price dispersion in the model is higher for goods that are relatively more intensive in distribution services.

The parameter which governs the idiosyncratic heterogeneity in productivity across goods in the Eaton-Kortum model can be chosen to match the variation in price dispersion, but this results in over-prediction of the average good-by-good price dispersion by a factor of 3. Furthermore, this critical parameter value is much smaller than the values actually estimated by Eaton and Kortum (2002). Sensitivity analysis reveals that more disaggregated and comparable data (across countries and goods) on distribution costs improves the performance of the model. Lastly, feeding good specific trade costs exogenously into the model and using distribution margins computed from consumption expenditure data enables the model to match the average price dispersion exactly and generate about 48 per cent of the variation in price dispersion.

In sum, the two sources of market segmentation emphasized in the literature - international trade costs and local costs of distribution - can explain the dispersion in LOOP deviations for an "average" retail product exactly, but the proportion of the variation in good-by-good price dispersion accounted for varies from a minimum of one-third to a maximum of one-half.

The rest of the paper is organized as follows. The next section discusses the micro price data. In section 3, I discuss the Ricardian trade model and its calibration, which is followed by a presentation of the baseline results in section 4. In section 5, I describe the data on distribution costs, and in section 6 I modify the Ricardian trade model to incorporate a distribution sector and discuss the calibration of this augmented model. This is followed by section 7 wherein I discuss results for the augmented model, and then I conduct sensitivity analysis in section 8. The last section concludes.

2 Measurement of LOOP Deviations

Denote retail price of good x in country i by $P_i(x)$ (description of the data is provided in Appendix A). The deviation from LOOP for good x in country i is $Q_i(x) = \log P_i(x) - \sum_{j=1}^{N} \log P_j(x)/N$, where N is the number of countries. Then standard deviation of $Q_i(x)$ across countries, given by $Var(Q_i(x)|x)^{1/2}$, is what the authors call "good-by-good price dispersion". I focus on two measures of good-by-good price dispersion: (i) the average good-by-good price dispersion, and (ii) the variation in good-by-good price dispersion.

Table 1: Good-by-Good Price Dispersion in Data

	1975	1980	1985	1990	Avg.
Avg.	0.2290	0.2941	0.3024	0.2855	0.2778
Max	0.7496	0.7751	0.8189	0.8319	0.7939
Min	0.0227	0.0784	0.0672	0.0458	0.0535
IQR	0.1297	0.1646	0.1749	0.1689	0.1595
P90 - P10	0.2427	0.2976	0.3281	0.3350	0.3008

The first row of Table 1 shows the average good-by-good price dispersion (average of $Var(Q_i(x)|x)^{1/2}$ over goods) for each of the four years, and also in the final column, the average of this measure over the four years. The average good-by-good price dispersion is about 28 percent over the four years. 1975 shows the smallest average price dispersion. However, it has remained quite stable for the other three years. The jump in price dispersion between 1975 and 1980 is argued to be due to a smaller sample of countries in the 1975 survey (9 out of the 13 countries). The same feature emerges in measures of variation in good-by-good price dispersion. The variation in good-by-good price dispersion is large, ranging from a minimum of 2 percent to a maximum of 83 percent, across the four years. However, I

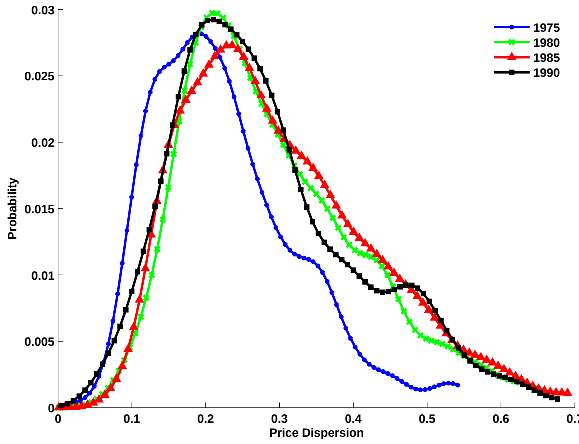


Figure 1: Empirical Distribution of $Var(Q_i(x)|x)^{1/2}$ in the Data

use the inter-quartile range (IQR) (difference between the 25^{th} and the 75^{th} percentile of good-by-good price dispersion) as the primary measure of variation in order to minimize the effect of extreme values on the measurement of variation in good-by-good price dispersion. IQR, averaged over the four years, is 0.16. I also report the difference between the 10^{th} and 90^{th} percentile of good-by-good price dispersion (P90 - P10), which is 0.30 when averaged over the four years. The fact that the value of P90 - P10 is almost double that of the IQR suggests that the distribution of good-by-good price dispersion is skewed. This is evident in Figure 1, which depicts the kernel density of good-by-good price dispersion (reproduced from Crucini et al. (2005)) for the four years.

3 Ricardian Trade Model

I start by discussing the the general equilibrium version of the Eaton and Kortum model, due to Alvarez and Lucas (2007). Consider a world with n countries. Country i ($i = 1, \ldots, n$) has L_i consumers and each consumer has 1 unit of labor, which is supplied inelastically (all variables are expressed in per capita terms) and k_i units of capital. Each country produces a continuum of base goods, indexed on the unit interval. Base good x, $x \in [0, 1]$, in country i is produced using a Cobb-Douglas technology

$$m_i(x) = z_i(x)^{-\theta} \left[k_i(x)^{\alpha} l_i(x)^{1-\alpha}\right]^{\beta} c_i(x)^{1-\beta} \quad ,$$

where $k_i(x)$, $l_i(x)$ and $c_i(x)$ are the amounts of capital, labor and intermediate composite, respectively, used to produce base good x in country i, and $z_i(x)$ is the inverse of the efficiency of country i in producing good x. In other words $z_i(x)$ is an idiosyncratic "cost". I assume that idiosyncratic cost of producing good x in country i is a random draw from a country-specific density $f_i = \exp(\lambda_i)$. The random cost draws are independent across goods, and the distributions are independent across countries. Further, these draws are amplified in percentage terms by the parameter θ. A larger θ represents a larger variance in costs of (producing) individual goods. λ_i determines country i's absolute advantage in producing any good x whereas θ controls the degree of comparative advantage.

Countries trade base goods. In each country there is a representative importing firm that buys each base good x, at the lowest price. Let $\overline{m}_i(x)$ be the amount of base good x that the importing firm in country i buys. Base goods are then combined in country i to produce an intermediate composite, c_i. This composite is a Spence-Dixit-Stiglitz (SDS) aggregator, with an elasticity of substitution, η, between goods:

$$c_i = \left[\int_0^\infty \overline{m}_i(z)^{1-\frac{1}{\eta}} f(z) dz \right]^{\frac{\eta}{\eta-1}} \quad .$$

Here each good, x, is identified by its cost draw, z, and $f(z)$ is the joint distribution of cost draws $((z_1(x), \ldots, z_n(x)))$, over countries. A representative consumer in every country i consumes a non-traded final good, y_i. The final good is produced using Cobb-Douglas technology with labor, l_{yi}, capital, k_{yi}, and intermediate composite, c_{yi}, as the inputs.

$$y_i = \left[k_{yi}^{\alpha} l_{yi}^{1-\alpha} \right]^{\rho} c_{yi}^{1-\rho} \quad .$$

Finally, the markets for the three inputs - intermediate composite, labor and capital - must clear.

$$\int_0^1 c_i(x) dx + c_{yi} \leq c_i \quad , \quad \int_0^1 l_i(x) dx + l_{yi} \leq 1 \quad , \quad \int_0^1 k_i(x) dx + k_{yi} \leq k_i \quad .$$

Let $c_{mi} = \int_0^1 c_i(x) dx$ denote the units of the intermediate composite used in the base good sector, $l_{mi} = \int_0^1 l_i(x) dx$ denote the share of base goods sector in the labor force, and $k_{mi} = \int_0^1 k_i(x) dx$ denote the units of capital used in the base good sector.

The object of interest in this baseline model is the price of an individual base good. Profit maximization in the two sectors - base goods and final good - implies that the return to capital in country i is $r_i = (\alpha/(1-\alpha)) w_i k_i^{-1}$, where w_i is the wage. Then, the domestic cost of producing base good x in country i is $Bz_i(x)^\theta w_i^\beta p_{ci}^{1-\beta} k_i^{-\alpha\beta}$, where $B = \beta^{-\beta}(1-\beta)^{(\beta-1)}\alpha^{-\alpha\beta}(1-\alpha)^{\beta(\alpha-1)}(\alpha/(1-\alpha))^{\alpha\beta}$. p_{ci} is the price of intermediate composite in country i

$$p_{ci} = \left[\int_0^\infty \overline{p}_{mi}(z)^{1-\eta} f(z) dz\right]^{\frac{1}{1-\eta}} \quad ,$$

where $\overline{p}_{mi}(z)$ is the price of the base good characterized by productivity level z, in country i. The importing firm in each country buys each good, x, from the lowest cost supplier of that good. However, to deliver 1 unit of a base good from country j to country i, country j must produce τ_{ij} units of the good. Due to geographic and other barriers to trade, $\tau_{ij} > 1$ for $i \neq j$, and $\tau_{ii} = 1$ for all i. This is the standard "iceberg assumption" *a la* Samuelson. Therefore, the price of good x in country i is given by:

$$\overline{p}_{mi}(x) = B \min_j \left[w_j^\beta p_{cj}^{1-\beta} k_j^{-\alpha\beta} \tau_{ij} z_j(x)^\theta\right] \quad . \tag{1}$$

In the absence of distribution costs, this is the retail price of good x.

3.1 Calibration Methodology and Simulation of Prices

In order to simulate the prices of individual base goods I solve for the vector of wages w and the vector of prices of the intermediate composite p_c and calibrate the vector of productivity parameters λ, given the matrix of estimated trade costs τ and the vectors of labor and capital endowments - L and k, respectively. I start by discussing the estimation of trade costs[5].

Let X_i be the per capita expenditure of country i on tradable goods. Define D_{ij} as the share of country i's per capita spending on tradables that is spent on goods from country j. For country j to supply good x to country i, j must be the lowest price seller of good x to i. Then,

$$D_{ij} = (AB)^{-1/\theta}\left(\frac{w_j^\beta p_{cj}^{1-\beta} k_j^{-\alpha\beta}\tau_{ij}}{p_{ci}}\right)^{-1/\theta} \lambda_j \quad , \tag{2}$$

and $\sum_{j=1}^n D_{ij} = 1$[6]. Eq. (2) implies that the share of country j in country i's total expenditure on tradables, normalized by country i's share in its own total expenditure on tradables,

[5] Unlike Alvarez and Lucas (2007), trade costs in the model are country-pair specific and asymmetric, rather than homogeneous.

[6] See Alvarez and Lucas (2007) for derivation.

is given by:

$$\frac{D_{ij}}{D_{ii}} = \frac{\left(w_j^{\beta} p_{cj}^{1-\beta} k_j^{-\alpha\beta} \tau_{ij}\right)^{-1/\theta} \lambda_j}{\left(w_i^{\beta} p_{ci}^{1-\beta} k_i^{-\alpha\beta}\right)^{-1/\theta} \lambda_i} \quad .$$

Let $\Omega_i = \left(w_i^{\beta} p_{ci}^{1-\beta} k_i^{-\alpha\beta}\right)^{-1/\theta} \lambda_i$, and $S_i = \ln(\Omega_i)$.

$$\Rightarrow \ln\left(\frac{D_{ij}}{D_{ii}}\right) = S_j - S_i - \frac{1}{\theta} \ln \tau_{ij} \quad . \tag{3}$$

The left-hand side of this equation is calculated from data on bilateral trade and gross output. The methodology used to calculate the left-hand side is explained in Appendix B. Trade costs are obtained by estimating Eq. (3). Since τ_{ij} is not observable, following Eaton and Kortum (2002), I proxy trade barriers by distance, language, border and membership of free trade regions. Specifically,

$$\ln \tau_{ij} = dist_N + brdr + lang + tblk_M + dest_i + \epsilon_{ij} \quad , \tag{4}$$

where $dist_N$ $(N = 1, \ldots, 6)$ is the effect of distance between i and j lying in the Nth interval, $brdr$ is the effect of i and j sharing a border, $lang$ is the effect of i and j sharing a language, $tblk_M$ $(M = 1, 2)$ is the effect of i and j belonging to trading area M, and $dest_i$ $(i = 1, \ldots, n)$ is a destination effect. The error term ϵ_{ij} captures trade barriers due to all other factors, and is orthogonal to the regressors. The six distance intervals (in miles) are: $[0, 375)$; $[375, 750)$; $[750, 1500)$; $[1500, 3000)$; $[3000, 6000)$ and $[6000, \text{maximum}]$. The two trading areas are the European Union (EU) and the North-American Free Trade Agreement (NAFTA) area. S_i is captured as the coefficient on source-country dummies.

Eq. (1) implies that the price of the intermediate composite[7] is given by

$$p_{ci} = AB\left(\sum_{j=1}^{n} \left(w_j^{\beta} p_{cj}^{1-\beta} k_j^{-\alpha\beta} \tau_{ij}\right)^{-1/\theta} \lambda_j\right)^{-\theta} \quad , \tag{5}$$

where $A = \left(\int_0^{\infty} h^{\theta(1-\eta)} e^{-h} dh\right)^{\frac{1}{1-\eta}}$[8]. The vector of wages is determined by imposing balanced trade - the revenue of country i must equal its expenditure.

$$\sum_{j=1}^{n} L_j X_j D_{ji} = L_i X_i \quad .$$

[7] See Alvarez and Lucas (2007) for the derivation.

[8] The integral in brackets is the Gamma function $\Gamma(\xi)$ evaluated at $\xi = 1 + \theta(1 - \eta)$. Convergence of this integral requires that $1 + \theta(1 - \eta) > 0$, which I assume holds throughout this paper.

In the base goods sector $L_i w_i l_{mi} = \beta(1-\alpha)\sum_{j=1}^{n} L_j X_j D_{ji} = \beta(1-\alpha)L_i X_i$. Since $l_{mi} = 1 - l_{yi} = 1 - \rho$, $\forall\ i$, the balanced trade condition can be written as

$$\sum_{j=1}^{n} L_j w_j D_{ji} = L_i w_i \quad . \tag{6}$$

Labor and capital for each country are obtained from the data[9]. Then, given the estimated trade cost matrix τ, Eq. (5) and Eq. (6) are used to solve for the equilibrium w and p_c, given an initial guess for λ. The guess for λ is updated by using Eq. (2), for $j = i$:

$$\lambda_i = (AB)^{1/\theta} \left[\frac{w_i}{p_{ci}}\right]^{\beta/\theta} k_i^{-\alpha\beta/\theta} D_{ii} \quad . \tag{7}$$

Therefore, Eq. (5), Eq. (6) and Eq. (7) form a system of $3n$ equations in $3n$ unknowns. In solving this system of equations, bilateral expenditure shares D_{ij} are replaced by their data counterparts, $\widehat{D}_{ij}$. This implies that the vector of productivity parameters, λ, is a function of bilateral trade shares observed in the data, adjusted for differences in endowments of labor and capital. A similar calibration strategy is adopted by Waugh (2007). Alvarez and Lucas (2007) calibrate λ by matching the relative price of non-tradables. I adopt a different calibration strategy for two reasons. First, since I am interested in characterizing the behavior of prices implied by the model, I choose not to use information on prices to calibrate λ. Second, and more importantly, one of the objectives of the paper is to evaluate whether the degree of market segmentation implied by flows of goods across borders can explain the deviations from the LOOP in prices of individual goods. By computing λ and τ as functions of bilateral trade shares, I impose the discipline on the model needed to answer this question.

Having obtained w_i, p_{ci}, λ_i, τ_{ij}, and k_i, I use Eq. (1) to simulate the prices of 1500 base goods. For each good, x, a cost vector $(z_1(x), \ldots, z_n(x))$ is drawn (where n is the number of countries) from the joint density function $f(z) = (\prod_{i=1}^{n} \lambda_i) \exp\{-\sum_{i=1}^{n} \lambda_i z_i\}$. The deviation from LOOP for a good in country i is computed as the log deviation of the price of the good

[9] I incorporate capital explicitly as an input, whereas it is only implicitly present in Alvarez and Lucas (2007). Although labor is the only input in their model, it is interpreted as 'equipped labor', i.e. labor equipped with capital.

in country i from the geometric-average (across countries) price of the good.

$$Q_{mi}(x) = \log p_{mi}(x) - \frac{\sum_{j=1}^{n} \log p_{mj}(x)}{n}, \quad x = \{1, \ldots, 1500\} \quad . \tag{8}$$

The cross-country dispersion in the LOOP deviations for a good x, denoted by $Var(Q_{mi}(x)|x)^{1/2}$, is going to be the measure of price dispersion for the good. Crucini et al. (2005) call this good-by-good price dispersion. Having computed this measure for each good, the objects of interest are going to be average price dispersion across goods and the IQR of price dispersion across goods.

3.2 Parameterization

There are 22 OECD countries in the sample[10]. In addition to the 13 EU countries included in Crucini et al. (2005), I include 9 other countries. Using only the 13 EU countries would not take into account all major trading partners of the countries. This will result in underestimation of total trade volume, consequently affecting the estimates of trade costs. Therefore, I choose a broader set of countries to account for as large a share of total trade as possible, at the same time ensuring that the chosen countries have similar levels of per capita GDP as those considered in Crucini et al. (2005). The model is calibrated to the year 1996. The choice of the year is driven by the availability of data on capital-labor ratios.

The traded goods sector includes agriculture, hunting, forestry and fishing, mining and quarying, and manufacturing. All other sectors form the final good sector. The parameter β is calibrated as the share of value added in gross output of the traded goods sector. Details of the data and the methodology are provided in Appendix B. For the sample of countries β is 0.36. α is the share of capital in GDP. Gollin (2002) finds that the share of labor in value added for a wide cross-section of countries is around 2/3, which implies that α is 0.33. ρ is the share of value added in gross output of the final good sector. Since the value of the output of the final good sector is the GDP of a country, ρ is calibrated as one minus the share of traded goods sector in GDP. I find that the share of traded goods sector in GDP is 0.25 which implies that ρ is 0.75. Following Alvarez and Lucas (2007), θ, which controls

[10] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

the variability of the national idiosyncratic component of productivity, is 0.15 and η, which is the substitution parameter, is 2[11]. The labor force vector $L = (L_1, \ldots, L_n)$ and the vector of capital-labor ratios $k = (k_1, \ldots, k_n)$ are taken from the data in Caselli (2005)[12]. Table 10, in Appendix C, summarizes the parameterization of the Ricardian model.

Table 2 reports the estimated coefficients for geographic barriers, the corresponding standard errors and the implied effect on cost relative to home sales. The costs imposed by trade barriers are comparable to the costs obtained by Eaton and Kortum (2002) both, quantitatively and qualitatively. Since I include all traded goods - agricultural goods, fuels and mining goods, and manufacturing goods - in computing bilateral trade shares, whereas Eaton and Kortum (2002) consider only manufacturing goods, I get slightly higher estimates of costs imposed by trade barriers.

Table 2: Geographic Barriers

Variable	Denoted by	Coefficient	Std. Error	% Effect on Cost
Distance [0,375)	$-\frac{1}{\theta}dist_1$	-3.76	0.16	75.85
Distance [375,750)	$-\frac{1}{\theta}dist_2$	-3.91	0.13	79.80
Distance [750,1500)	$-\frac{1}{\theta}dist_3$	-4.25	0.12	89.09
Distance [1500,3000)	$-\frac{1}{\theta}dist_4$	-4.47	0.17	95.43
Distance [3000,6000)	$-\frac{1}{\theta}dist_5$	-6.26	0.08	155.67
Distance [6000,maximum]	$-\frac{1}{\theta}dist_6$	-6.65	0.09	171.15
Shared Border	$-\frac{1}{\theta}brdr$	0.65	0.13	-9.34
Shared Language	$-\frac{1}{\theta}lang$	0.30	0.10	-4.41
EU	$-\frac{1}{\theta}tblk_1$	0.19	0.14	-2.88
NAFTA	$-\frac{1}{\theta}tblk_2$	-0.39	0.35	6.01
Destination Country				
Australia	$-\frac{1}{\theta}dest_1$	1.03	0.24	-14.38
Austria	$-\frac{1}{\theta}dest_2$	-1.45	0.18	24.31
Belgium	$-\frac{1}{\theta}dest_3$	0.74	0.18	-10.55
Canada	$-\frac{1}{\theta}dest_4$	1.42	0.24	-19.13
Denmark	$-\frac{1}{\theta}dest_5$	-0.69	0.18	10.90
Finland	$-\frac{1}{\theta}dest_6$	-1.21	0.18	19.86
France	$-\frac{1}{\theta}dest_7$	0.08	0.18	-1.12
Germany	$-\frac{1}{\theta}dest_8$	1.07	0.18	-14.85
Greece	$-\frac{1}{\theta}dest_9$	-2.92	0.18	55.07
Ireland	$-\frac{1}{\theta}dest_{10}$	-0.76	0.17	12.01
Italy	$-\frac{1}{\theta}dest_{11}$	0.06	0.18	-0.85
Japan	$-\frac{1}{\theta}dest_{12}$	2.20	0.21	-28.11
Mexico	$-\frac{1}{\theta}dest_{13}$	-0.63	0.22	9.89
Netherlands	$-\frac{1}{\theta}dest_{14}$	0.95	0.18	-13.29
New Zealand	$-\frac{1}{\theta}dest_{15}$	0.03	0.24	-0.43
Norway	$-\frac{1}{\theta}dest_{16}$	-0.62	0.23	9.82
Portugal	$-\frac{1}{\theta}dest_{17}$	-2.26	0.18	40.34

[11] Value of η is important only for the convergence of the gamma function and it does not have any implications for the results of the model.

[12] I thank Michael E. Waugh for sharing this data with me.

Table 2: (continued)

Variable	Denoted by	Coefficient	Std. Error	Implied % Effect on Cost
Spain	$-\frac{1}{\theta}dest_{18}$	-0.64	0.17	10.01
Sweden	$-\frac{1}{\theta}dest_{19}$	0.01	0.17	-0.16
Switzerland	$-\frac{1}{\theta}dest_{20}$	-0.60	0.22	9.44
United Kingdom	$-\frac{1}{\theta}dest_{21}$	1.10	0.18	-15.25
United States	$-\frac{1}{\theta}dest_{22}$	3.09	0.45	-37.06
R-Square = 0.9221	Adj.R-Square = 0.9122	N Obs = 462		

Note: Given an estimated coefficient, b, the implied percentage effect on cost is estimated as $100(e^{-\theta b} - 1)$.

4 Results: Ricardian Model

Table 3 compares the model generated good-by-good price dispersion with that observed in the data. Remarkably, this multi-country Ricardian model can account for 85 percent of the average good-by-good price dispersion observed in the data. However, with respect to the variation in good-by-good price dispersion, as measured by IQR, the model can generate 21 percent of the variation observed in the data. The model does a little better in terms of P90 - P10 as it can generate about 24 percent of the variation observed in the data, which suggests that the distribution of good-by-good price dispersion generated by the model exhibits some skewness. This becomes clear from the empirical distribution of the good-by-good price dispersion obtained from the model, shown in Figure 2.

Table 3: Good-by-Good Price Dispersion: Model Versus Data

	Model	Data	Model as ratio of Data
Avg.	0.2365	0.2778	0.8513
IQR	0.0341	0.1595	0.2138
P90 - P10	0.0708	0.3008	0.2354

These results suggest that, for the average retail good, the degree of goods' market segmentation implied by trade barriers is quite consistent with the degree of segmentation implied by dispersion of LOOP deviations. However, the trade barriers implied by observed bilateral trade volumes are not large enough to account for the average price dispersion fully. More importantly, despite allowing for heterogeneity and asymmetry in international trade costs, a Ricardian model with trade costs does poorly in matching the variation in good-by-good price dispersion observed in the data.

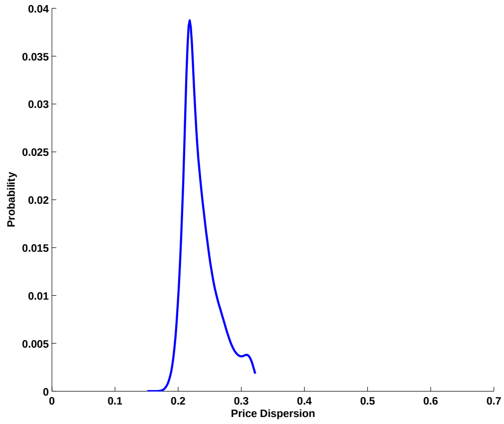


Figure 2: Distribution of $Var(Q_{mi}(x)|x)^{1/2}$: Ricardian Model

5 Data on Distribution Costs

In this section, I explore the potential for distribution costs to account for the variation in good-by-good price dispersion. Following Goldberg and Campa (Forthcoming), I compute distribution margins - distribution costs as a ratio of retail value - for 29 product categories in each country. The data come from input-output tables, specifically the use tables, which provide information on the value of the supply of goods in "basic price" and the value of the same goods in "purchaser price". The difference between basic price and purchaser price is that the latter includes distribution margins and value added taxes (or subsidies), whereas the former does not. The distribution margin for a good is calculated as:

$$\text{Distribution Margin} = \frac{\text{Supply in Purchaser Prices} - \text{Supply in Basic Prices}}{\text{Supply in Purchaser Prices}}$$

Care is taken to exclude net taxes from the purchaser price value of each good[13]. For the EU countries, goods are classified according to the Classification of Products by Activities (CPA) classification of goods. Australia, New Zealand, the United States and Japan do not use the CPA classification of goods. Since the EU countries form the majority of countries in my sample the commodity classifications of the non-EU countries were mapped into the CPA classification. Only those product categories were chosen for which the distribution margins were non-negative. The data show that distribution margins are zero or negative

[13]For Japan and the United States, data on net taxes are not available. Therefore, for these countries purchaser price value could not be adjusted for net taxes.

for almost all services across countries. This is consistent with the findings of Goldberg and Campa (Forthcoming). In addition, the CPA product category 'Uranium and thorium ores' was excluded because of missing data. For most countries in the sample data are available for the year 1995. For Australia, data are available for 2001-02, for Norway they are available for 2001, for Ireland they are available for 1998 and for the United States they are available for 1997. Data are not available for Canada, Mexico and Switzerland.

For the countries for which I have data over multiple years, I find that distribution margins do not change significantly from one year to another for individual product categories. Consequently, the inconsistency between the years for which distribution costs data are available and the year to which the benchmark model is calibrated (1996) is a non-issue.

Table 4 provides three statistics on distribution margins by country across goods - the average, the maximum and the minimum value. The second column shows that Japan has the highest average distribution margin whereas Ireland has the lowest[14]. The last two columns show that within each country there is a large variation in distribution margins across goods.

Table 4: Distribution Margins by Countries

Country	Average	Maximum	Minimum
Australia	0.2329	0.5698	0.0794
Austria	0.1833	0.4408	0.0000
Belgium	0.1540	0.3800	0.0569
Denmark	0.1952	0.3993	0.0000
Finland	0.1683	0.6302	0.0233
France	0.1567	0.3832	0.0107
Germany	0.2012	0.4658	0.0677
Greece	0.2063	0.4734	0.0001
Ireland	0.1022	0.2728	0.0000
Italy	0.2041	0.4768	0.0040
Japan	0.3361	0.9275	0.1015
Netherlands	0.1752	0.4382	0.0004
New Zealand	0.1338	0.2825	0.0000
Norway	0.2352	0.7141	0.0000
Portugal	0.1489	0.3974	0.0000
Spain	0.1644	0.4301	0.0003
Sweden	0.1612	0.4851	0.0000
United Kingdom	0.1810	0.4921	0.0010

[14]These numbers are based on distribution margins for all expenditures. Burstein et al. (2003), using data only on final consumption expenditure, show that distribution margins are higher - average of 40 percent for U.S., and 60 percent for Argentina. However such data are not available at the good level for most countries in my sample.

Table 4: (continued)

Country	Average	Maximum	Minimum
United States	0.2753	0.7215	0.0537

Table 5 lists the average, the maximum and the minimum distribution margin across countries for each CPA product category. 'Wearing apparel; furs' has the highest average distribution margin across countries. On the other hand 'Other transport equipment' has the lowest average margin. Looking at the last two columns, it is clear that even for the same good there is significant variation in distribution margins across countries.

Table 5: Distribution Margins by Goods

CPA Product	Average	Maximum	Minimum
Products of agriculture, hunting and related services	0.1662	0.3015	0.0141
Products of forestry, logging and related services	0.1449	0.4301	0.0000
Fish and other fishing products; services incidental of fishing	0.2424	0.4768	0.0000
Coal and lignite; peat	0.1530	0.6833	0.0000
Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying	0.1022	0.8925	0.0000
Metal ores	0.1262	0.9275	0.0000
Other mining and quarrying products	0.2015	0.4109	0.0000
Food products and beverages	0.2187	0.3901	0.0954
Tobacco products	0.3650	0.7141	0.1102
Textiles	0.2250	0.4327	0.0978
Wearing apparel; furs	0.3979	0.6000	0.2112
Leather and leather products	0.3582	0.7215	0.1237
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials	0.1452	0.3085	0.0306
Pulp, paper and paper products	0.1383	0.2282	0.0472
Printed matter and recorded media	0.1657	0.2752	0.0570
Coke, refined petroleum products and nuclear fuels	0.2118	0.4323	0.0000
Chemicals, chemical products and man-made fibres	0.1827	0.2767	0.0348
Rubber and plastic products	0.1468	0.2647	0.0523
Other non-metallic mineral products	0.1730	0.2906	0.0574
Basic metals	0.1013	0.1633	0.0371
Fabricated metal products, except machinery and equipment	0.1400	0.2728	0.0718
Machinery and equipment n.e.c.	0.1499	0.2632	0.0410
Office machinery and computers	0.2073	0.3993	0.0448
Electrical machinery and apparatus n.e.c.	0.1537	0.3557	0.0581
Radio, television and communication equipment and apparatus	0.1513	0.2384	0.0729
Medical, precision and optical instruments, watches and clocks	0.2099	0.3975	0.0667
Motor vehicles, trailers and semi-trailers	0.1815	0.3376	0.0744
Other transport equipment	0.0819	0.2825	0.0213
Furniture; other manufactured goods n.e.c.	0.2904	0.4821	0.1300

It is clear from the data that distribution margins vary widely across goods and across countries. Using this data, I incorporate heterogeneity in distribution margins in the model and evaluate its importance in driving the dispersion in LOOP deviations. The cross-country and cross-product trends in distribution margins are the same as those reported by Goldberg and Campa (Forthcoming). The size of distribution margins is also similar[15], with some difference arising because for some countries they use data from a different year. Furthermore, in addition to the countries listed in Table 4, they include Estonia, Hungary and Poland.

6 Ricardian Trade Model with A Local Distribution Sector

In this section I extend the benchmark multi-country Ricardian trade model to account for local costs of distribution. Now, base goods, besides being used to produce the intermediate composite, are also delivered to the consumer as retail goods. A retail good is produced by combining distribution services and a base good (whether produced domestically or imported). Distribution services and retail goods are not traded.

The production technology of base goods is unchanged. However, now, the amount of base good x bought by the importing firm, $\overline{m}_i(x)$, is divided into two parts.

$$\overline{m}_i(x) = \overline{m}_{ci}(x) + \overline{m}_{qi}(x) \quad .$$

$\overline{m}_{ci}(x)$ is used to produce the intermediate composite in country i and $\overline{m}_{qi}(x)$ is bought by the retailer of good x in country i. The production technology for intermediate composite good also remains unchanged.

$$c_i = \left[\int_0^\infty \overline{m}_{ci}(z)^{1-\frac{1}{\eta}} f(z)dz\right]^{\frac{\eta}{\eta-1}} \quad .$$

The retailer of good x combines $\overline{m}_{qi}(x)$ with distribution services to deliver the base good to the consumer in the form of a retail good. Output of retail good, x, is denoted by $m_{qi}(x)$. Distribution services, d_i, are produced using Cobb-Douglas technology with labor, l_{di}, capital, k_{di}, and intermediate composite, c_{di}, as the inputs.

$$d_i = [k_{di}^{\alpha} l_{di}^{1-\alpha}]^{\delta} c_{di}^{1-\delta} \quad .$$

[15]Goldberg and Campa (Forthcoming) compute average distribution margin as one minus the ratio of total supply of all goods in basic prices to total supply in purchaser's prices. This is different from averaging the distribution margins across product categories, as I do.

To deliver 1 unit of base good x to the consumer, $\phi_i(x)$ units of distribution services are required,

$$\phi_i(x) = \zeta_i u(x)^\nu \quad ,$$

where ζ_i denotes the units of distribution services required to deliver any good to the consumer in country i, and reflects country i's efficiency in distribution of goods, and u is a random draw from a common density function $g = \exp(1)$. The draws are assumed to be independent across goods. For a given base good x, u and z (random cost draw for base good x) are also assumed to be independent.

Bringing one unit of a base good to the consumer requires a fixed proportion of distribution services. This assumption is made in the spirit that production and retailing are complements, and consumers consume them in fixed proportions. Erceg and Levin (1996), Burstein et al. (2003) and Corsetti and Dedola (2005) also adopt the same production structure for retail goods. However, I allow the units of distribution services used to deliver a unit of a good to vary across goods, as well as countries, whereas these studies do not. Furthermore, these studies, for simplicity, do not differentiate between nontradable consumption goods, which directly enter the agents' utility, and nontraded distribution services, which are jointly consumed with traded goods. However, I make this distinction. This is necessary because the parameters ν and ζ_i, which govern heterogeneity in the use of distribution services, are calibrated using the data on distribution margins and not from the data on all services.

Therefore, in addition to producing distribution services each country also produces a homogeneous non-traded good. Production of the non-traded good also combines labor, l_{si}, capital, k_{si}, and the intermediate composite, c_{si}, using a Cobb-Douglas technology.

$$s_i = [k_{si}^\alpha l_{si}^{1-\alpha}]^\gamma c_{si}^{1-\gamma} \quad .$$

The consumer in country i consumes a final good, y,

$$y_i = q_i^\mu s_i^{1-\mu} \quad ,$$

where q_i is a composite retail good.

$$q_i = \left[\int_0^1 m_{qi}(x)^{1-\frac{1}{\eta}} dx\right]^{\frac{\eta}{\eta-1}} \quad .$$

The markets for the intermediate composite, labor and capital must clear, and the total units of distribution services required to deliver base goods to the consumer cannot exceed the output of distribution services.

$$\int_0^1 \phi_i(x)\overline{m}_{qi}(x)dx \leq d_i \quad .$$

The price at which the importing firm buys good x, $\overline{p}_{mi}(x)$, remains unchanged and is given by Eq. (1). However, now I am going to refer to this as the producer price of good x. The retail price of base good x is the sum of the producer price of good x and the value of distribution services used to deliver 1 unit of the good.

$$p_{mi}(x) = \overline{p}_{mi}(x) + \phi_i(x)p_{di} \quad . \tag{9}$$

The price of distribution services, p_{di}, is given by

$$p_{di} = Cw_i^{\delta}p_{ci}^{1-\delta}k_i^{-\alpha\delta} \quad , \tag{10}$$

where $C = \delta^{-\delta}(1-\delta)^{(\delta-1)}\alpha^{-\alpha\delta}(1-\alpha)^{\delta(\alpha-1)}(\alpha/(1-\alpha))^{\alpha\delta}$. Eq. (9) shows that the retail price of good x is going to differ across countries for two reasons: (i) the producer price can be different across countries because of the presence of trade costs, and (ii) the costs of distribution can be different across countries because of differences in the price of distribution services, and differences in the number of units of distribution services used.

Since $\overline{p}_{mi}(x)$ is unchanged, it implies that the price of intermediate composite is also unchanged and is given by Eq. (5).

6.1 Calibration Methodology and Simulation of Prices

The zero profit condition in the retail goods sector implies that $L_iV_{mi} = L_i\overline{V}_{mi} + L_ip_{di}d_i$. V_{mi} is the per capita retail value of all base goods, and $\overline{V}_{mi}$ is the per capita producer price value of all base goods. Define ϑ_i as the ratio of value of distribution services and retail value of base goods in country i, i.e. $\vartheta_i = L_ip_{di}d_i/L_iV_{mi}$. With the inclusion of a distribution sector, the share of the base goods sector in the labor force is $l_{mi} = 1 - l_{di} - l_{si} = 1 - \mu\delta\vartheta_i - \gamma(1-\mu)$. Now, the balanced trade condition is given by:

$$\sum_{j=1}^{n} L_jw_jl_{mj}D_{ji} = L_iw_il_{mi} \quad . \tag{11}$$

The solution methodology remains the same; I take the endowment of labor and capital from data, and estimate trade costs from the gravity equation, Eq. (3), solve for w_i and p_{ci} using Eq. (11) and Eq. (5), and calibrate λ_i using Eq. (7). ϑ_i is estimated from the data (see Appendix B for details).

In order to simulate the retail prices I simulate the producer prices and the units of distribution services used. The prices are simulated for 1500 goods. For each good, x, a cost vector $(z_1(x), \ldots, z_n(x))$ is drawn, where n is the number of countries, from the joint density function $f(z) = (\prod_{i=1}^{n} \lambda_i) \exp\{-\sum_{i=1}^{n} \lambda_i z_i\}$. Using Eq. (1), I calculate producer prices of goods. Then, for each country i, a vector $(u_i(1), \ldots, u_i(M))$, where M is the number of goods, is drawn from the density function $g = e^{-u}$. Each element of the vector represents the units of distribution services used in delivering good x to the consumer. The retail price of each good is calculated using Eq. (9). The deviation from the LOOP, $Q_{mi}(x)$, is computed using Eq. (8), but for retail prices. Good-by-good price dispersion is given by $Var(Q_{mi}(x)|x)^{1/2}$.

The distribution margin for good x is calculated as:

$$dm_i(x) = 1 - \frac{\overline{p}_{mi}(x)}{p_{mi}(x)} \quad . \tag{12}$$

6.2 Parameterization

As in the Ricardian model, agriculture, hunting, forestry and fishing, mining and quarying, and manufacturing are treated as the traded goods sector. Wholesale trade, retail trade and transport and storage form the distribution services sector. All other sectors form the non-traded good sector. The calibrated values of β, α, η and θ remain unchanged. δ and γ are calibrated as the share of value added in gross output of distribution services sector and the non-traded good sector, respectively. μ is the share of the composite retail good in value of output of the final good sector. Since the value of output of the final good sector is the GDP of a country, μ is computed as one minus the share of the non-traded good sector (all services except retail trade, wholesale trade and transport and storage) in GDP. Details of the data and the methodology are provided in Appendix B. For the sample of countries δ is 0.58, γ is 0.62 and μ is 0.42. Again, these are averages for the period 1995-1997.

Heterogeneity in distribution margins is used as a target to calibrate ν. First, using the model simulated distribution margins, the standard deviation of distribution margins across all goods in each country is computed. Then, an average of these country-specific standard deviations is computed. ν is chosen so that this model generated average standard deviation is equal to its data counterpart (which is 11.5 percent). I find ν to be 0.75. ζ_i is chosen so that the average of the simulated distribution margins of all goods in country i equals the average of distribution margins of all goods in country i observed in the data (as reported in Table 4). The average distribution margin for countries with missing data (Canada, Mexico and Switzerland) is replaced by the sample average in the data. Table 6 gives the calibrated ζ for each country.

Table 6: Country-Specific Distribution Parameter: ζ_i

Country	ζ	Country	ζ	Country	ζ	Country	ζ
Australia	0.33	Finland	0.15	Italy	0.18	Spain	0.19
Austria	0.21	France	0.14	Japan	0.37	New Zealand	0.16
Belgium	0.11	Germany	0.17	Mexico	0.23	Sweden	0.12
Canada	0.22	Greece	0.23	Netherlands	0.14	Switzerland	0.17
Denmark	0.19	Ireland	0.06	Norway	0.20	United Kingdom	0.18
				Portugal	0.17	United States	0.30

Table 10, in Appendix C, summarizes the parameterization of the Ricardian model with distribution sector.

7 Results: Ricardian Model with Distribution

Accounting for the differences in costs of distribution across goods and across countries helps the model to better match the data. Table 7 shows that the model accounts for 96.5 percent of the average price dispersion observed in the data. Furthermore, the model can account for 32 percent of the IQR (inter-quartile range) observed in the data.

Table 7: Good-by-Good Price Dispersion: Model Versus Data

	Model	Data	Model as ratio of Data
Avg.	0.2680	0.2778	0.9648
IQR	0.0505	0.1595	0.3167
P90 - P10	0.0978	0.3008	0.3251

Figure 3 plots the empirical distribution of good-by-good price dispersion generated by the Ricardian model with distribution, as well as that generated by the benchmark Ricardian model. Notice that the distribution generated by the Ricardian model with distribution is more symmetric than the distribution generated by the benchmark Ricardian model. This is due to the fact that the improvement in matching the data brought about by including

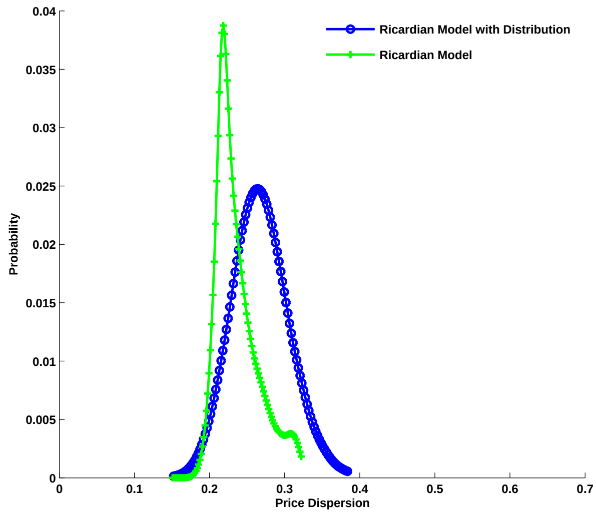
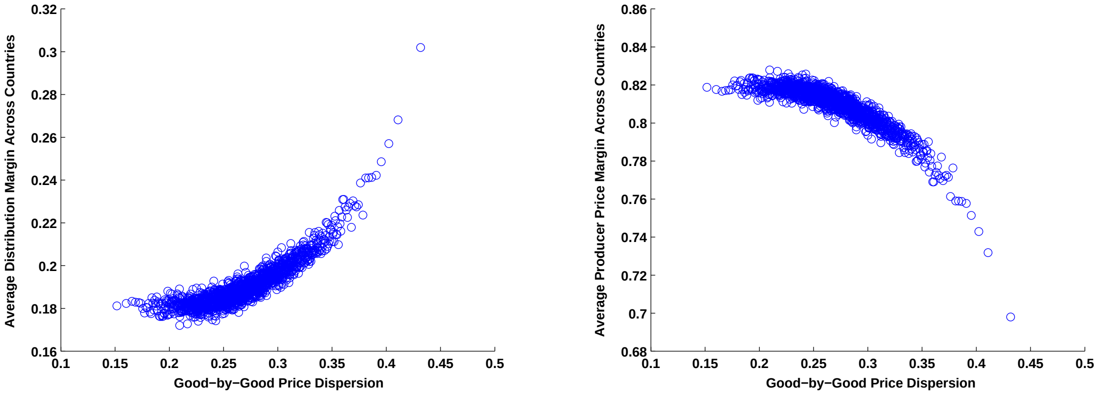


Figure 3: Distribution of $Var(Q_{mi}(x)|x)^{1/2}$

distribution costs generates a 38 percent improvement in matching P90 - P10, which is lower than the 48 percent improvement in accounting for IQR. Overall, the results show that distribution costs play a more important role in matching the variation in good-by-good price dispersion than in matching the average good-by-good price dispersion in retail prices observed in the data.

How is good-by-good price dispersion related to the use of traded and non-traded inputs? The share of non-traded input in the retail price of a good is given by the distribution margin, whereas the share of traded input is the ratio of producer price to the retail price of a good. Let us call this the producer price margin. The next figure shows the relationship between the dispersion in LOOP deviations of a good and the average distribution margin (and producer price margin), across countries, of a good. Figure 4(a) shows that goods with higher price dispersion have a higher average distribution margin. Since the producer price margin is one minus the distribution margin, the average producer price margin falls as good-by-good price dispersion rises. The good with the highest dispersion in LOOP deviations has an average distribution margin of 30 percent whereas the good with the lowest dispersion has an average distribution margin of 18 percent. Thus, retail goods that are intensive in non-traded inputs show higher price dispersion as compared to those that are intensive in traded-inputs.



(a) Non-traded - Distribution Margin (b) Traded - Producer Price Margin

Figure 4: Good-by-Good Price Dispersion Versus Intensity of Traded and Non-traded Inputs

8 Can the Model do Better?

So, the model augmented with distribution costs can account for only one-third of the variation in good-by-good price dispersion. Can the model do a better job? The parameters of the model that control the heterogeneity in prices across goods are θ and ν. In this section I examine the quantitative importance of each of these parameters in generating good-by-good price dispersion. I also explore the effects of incorporating good specific trade costs.

8.1 Magnitude of θ

As explained earlier, θ governs the heterogeneity in costs (or idiosyncratic productivity) across goods. In other words, a given draw of z has a much larger impact on the production cost of a base good if θ is large. Therefore, a large θ results in greater dispersion in costs of production of base goods across countries. Furthermore, the magnitude of trade costs (estimated in Eq. (3)) also depends on the value of θ. A higher θ results in higher implied percentage effect on costs of selling goods to another country relative to selling goods at home[16].

Table 8: Effect of θ on Good-by-Good Price Dispersion

Value of θ	Avg.	IQR	P90 - P10
0.08	0.1952	0.0473	0.0904
0.15 (benchmark)	0.2680	0.0505	0.0978
0.28	0.3939	0.0679	0.1307

Table 8 shows the effect of a change in value of θ on good-by-good price dispersion. The benchmark value (value used in the model) of θ is 0.15. The other values considered are the upper and lower bounds of the range of values estimated by Eaton and Kortum (2002) (θ in this model is the inverse of that used in Eaton and Kortum (2002)). The benchmark value lies between the two bounds. The results show the dual implications of changing the magnitude of θ: (i) as θ increases the average good-by-good price increases because of a rise in the magnitude of trade costs, and (ii) as θ increases the variation in price dispersion increases

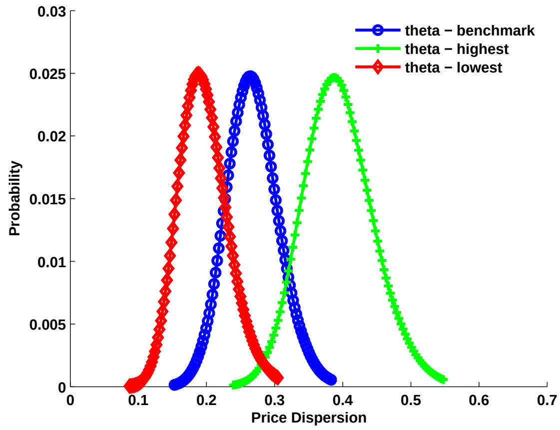


Figure 5: Effect of θ on Empirical Distribution of $Var(Q_{mi}(x)|x)^{1/2}$

and also becomes wider with an increase in θ, as depicted in Figure 5.

This also implies that one cannot pick a value of θ to match both the average price dispersion as well as the variation in price dispersion. What are the values of θ that would match the two moments of the price data? I find that with a $\theta = 0.1593$ the model can match the average price dispersion observed in the data. Among the values of θ estimated by Eaton and Kortum (2002), $\theta = 0.12$ (i.e. $\theta = 8.28$ in the Eaton-Kortum setup) is obtained using information on prices. The model implies the following relationship between trade volumes and price indices between two countries - $D_{ij}/D_{jj} = (p_{cj}\tau_{ij}/p_{ci})^{-1/\theta}$. To compute the ratio of price indices (p_{cj}/p_{ci}) for a trading pair the authors compute ratio of retail prices (between trading pairs) of 50 manufactured products and take an average over these ratios. τ_{ij} is taken to be equal to the second-highest ratio of retail prices among the 50 products. θ is the method-of-moments estimator obtained from this structural relationship. This value of θ, therefore, is consistent with average price differences across countries, given the trade volumes and trade costs, for a much smaller basket of goods. However, it is lower than $\theta = 0.1593$, which is the value required to match the average price dispersion. For $\theta = 0.12$, the average price dispersion generated by the model is 0.24 (explaining 85 percent of the average), whereas the IQR is 0.05 (explaining 30 percent of the variation).

With $\theta = 0.1593$ the model explains 32 percent of the variation in price dispersion. To match the variation in price dispersion the model requires a θ of 0.81 (which is equivalent to 1.24 in the Eaton-Kortum setup). But, as explained earlier, a higher θ results in higher average price dispersion too - the model overpredicts the average by a factor of three.

8.1.1 Magnitude of ν

In the model distribution services are used to deliver goods to the final consumers; they are not used to deliver the intermediate composite to firms. Therefore, the ideal data to calibrate the parameters of the distribution sector, ζ_i and ν, are data on distribution margins for final consumption expenditure of households. The data on distribution margins used in the model is based on all expenditures. Distribution margins based on final consumption expenditure are not available at the good level for most countries in the sample[17], but are available for the U.S.. Therefore, I use data from the BEA (Bureau of Economic Analysis) to compute distribution margins for final consumption expenditure of households across the 29 product categories. ν is chosen so that the model generated dispersion in distribution margins across goods is equal to the dispersion of distribution margins observed in the U.S. data. The data show that the dispersion of distribution margins for final consumption expenditure of households is higher than the average OECD dispersion in distribution margins (for all expenditure) used in the benchmark parameterization. Due to the lack of this disaggregated data on distribution margins for final consumption expenditure for other countries I compute the ratio of average distribution margin based on final consumption expenditure to average distribution margin based on all expenditures for the U.S. (the ratio is 1.54), and then multiply the average distribution margins of all other countries based on all expenditures with this ratio. This approximation assumes that the ratio of average distribution margin based on consumption expenditures to that based on all expenditures in all countries is equal to the ratio in the U.S.. ζ_i is chosen to match the resulting average distribution margin based on final consumption expenditures in country i[18].

The new value of ν is 1.02, which is higher than 0.75 obtained in the benchmark

[17] At the level of countries, the data shows that distribution margins for final consumption expenditure by households is higher than the distribution margin for all expenditure. See Goldberg and Campa (Forthcoming) and Burstein et al. (2003).

[18] ϑ_i is now computed as 1 minus the ratio of basic price value of final consumption expenditure by households on all traded goods to purchaser price value of final consumption expenditure by households on all traded goods.

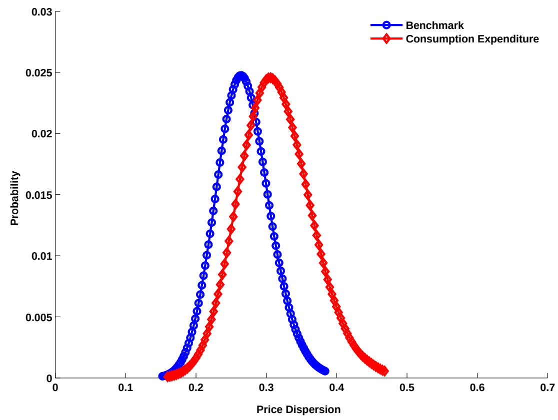


Figure 6: Effect of ν and ζ_i on Empirical Distribution of $Var(Q_{mi}(x)|x)^{1/2}$

parametrization. The higher value of ν generates greater heterogeneity, across goods, in the value of distribution services used to deliver goods, and hence increases good-by-good price dispersion. The higher average distribution margins (based on final consumption expenditure) make all goods in a country more intensive in distribution services. This should increase the average good-by-good price dispersion. The results are depicted in Figure 6. There is a clear increase in the spread of the distribution - IQR is 0.0683 when ν and ζ_i are calibrated to match distribution margins based on consumption expenditure data, as compared to IQR of 0.0505 in the benchmark model. Thus, now, the model can account for 43 percent of the variation in good-by-good price dispersion. There is also an increase in the average price dispersion - 0.3132, which is higher than that observed in the data, implying on overprediction of the average price dispersion by 12.75 percent.

8.2 Good Specific Hetereogeneity in Trade Costs

What is the effect of allowing for good-specific heterogeneity in trade costs? To answer this question, trade cost for good x from country j to country i is assumed to be log-normally distributed with parameters (ς_{ij}, σ). Then, the mean trade cost over all goods from j to i is given by $\exp(\varsigma_{ij} + \sigma^2/2)$ and the variance is given by $\exp(2\varsigma_{ij} + \sigma^2)\exp(\sigma^2 - 1)$. It is assumed that $\exp(\varsigma_{ij} + \sigma^2/2) = \tau_{ij}$, where τ_{ij} is the bilateral trade cost from j to i as estimated from the gravity equation. To get an estimate of the variance I rely on evidence from Hummels (2001), who computes trade weighted average freight rates (freight cost as a percentage of imports, aggregated over all partners for 1994) for United States, Argentina, Brazil, Chile, Paraguay, Uruguay, New Zealand by 2 digit SITC commodity codes. I assume that the variance in good-specific trade costs is the same for all importer-exporter pairs. I consider two values for the variance: (a) variance in freight rates in United States (17.45), and (b) variance in freight rates in New Zealand (105.52). This may be an imperfect measure, but it provides a reasonable benchmark. As a simplification, the good-specific trade costs are fed in exogenously, given the solution of the aggregates $(w_i, p_{ci}, p_{di}, \lambda_i, \tau_{ij})$ and the parameter values in the model with distribution costs. Only the parameters of the distribution sector are re-estimated to ensure that the size and dispersion of distribution margins is the same as in the data. The log-normal distributions are independent across exporter-importer pairs.

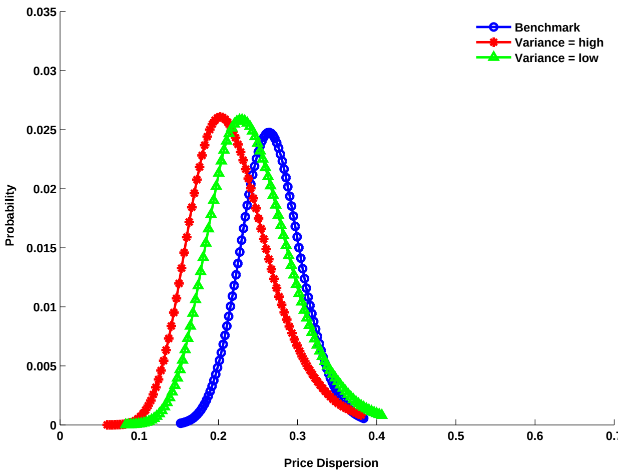


Figure 7: Effect of Good-Specific Heterogeneity in Trade Costs

The results are depicted in Figure 7. The density labeled benchmark is from the model with heterogeneous distribution costs and bilateral trade costs that are heterogeneous and asymmetric, but are not good specific. As compared to this benchmark, when trade costs are good specific and the variance is set at the lower end (variance in United States), the density shifts to the left and also becomes broader. This implies that the model's performance improves in explaining the variation in good-by-good price dispersion, but worsens in accounting for the average price dispersion. The same pattern is observed as variance is increased to the the higher value (variance in New Zealand). As the variance increases, keeping the mean the same (ς_{ij}), the distribution of trade costs across goods for a trading pair becomes skewed to the right. Thus, the mass of the trade cost density is concentrated towards the lower levels of trade costs, which results in lower average producer price dispersion and hence in lower average price dispersion for retail goods. This causes the leftward shift of the density of good-by-good price dispersion. The increased variation in price dispersion is driven by increased variance, and increased skewness, of the densities of trade costs. With the variance in trade costs set at the lower value, the model generates an average price dispersion of 0.2447 (explaining 88 percent of the average), and an IQR of 0.069 (explaining 43 percent of the variation). The corresponding numbers for the higher variance case are 0.22 (explaining 79 percent of the average) and 0.0684 (explaining 43 percent of the variation)[19]. The model is able to capture the left tail of the distribution of good-by-goof price dispersion much better.

Lastly I combine the good-specific heterogeneity in trade costs with calibration of ν and ζ_i based on distribution margins computed from data on final consumption expenditures. The variance of trade costs is assumed to be the average of the variance in freight costs of the United States and New Zealand. The average good-by-good price dispersion is 0.2803 and the IQR is 0.07612. Thus, this variant of the model can match the average good-by-good price dispersion perfectly and can account for 48 percent of the variation in price dispersion. As compared to the other variants, this variant is able to come closest to the data.

9 Conclusion

This paper poses two questions. First, is the degree of international goods market segmentation implied by trade flows consistent with that implied by deviations from LOOP? Second, can accounting for differences in local costs of distribution across goods and across countries, help to better match the data on LOOP deviations?

With respect to the first question, a standard multi-country Ricardian trade model, featuring bilateral heterogeneous and asymmetric trade costs, does a good job of matching the average good-by-good price dispersion; it explains 85 percent of the data. However, it is not able to generate the variation in good-by-good price dispersion observed in the data; it explains 21 percent. With respect to the second question, I find that accounting for

[19]The almost equal IQR with high and low variance is because IQR does not capture the increasing skewness of good-by-good price dispersion.

differences in costs of distribution across goods and across countries significantly improves the model's performance. This augmented model can generate 96.5 percent of the average price dispersion and 32 percent of the variation in price dispersion. The degree of price dispersion is higher for goods that are relatively more intensive in distribution services.

Furthermore, the parameter θ, which governs the idiosyncratic heterogeneity in productivity or cost across goods, can be chosen to match the variation in price dispersion; but the inability to disentangle the estimation of θ from that of trade costs results in overprediction of the average good-by-good price dispersion by a factor of 3. And this value of θ is much smaller than the values of θ estimated by Eaton and Kortum (2002). The price data certainly raise the question of what is the right estimate (or a range of estimates) of θ, an idea to be explored in future work. Sensitivity analysis reveal that more disaggregated and comparable data (across countries and goods) on distribution costs will help in improving the performance of the model. Lastly, feeding good specific (and bilateral trade pair specific) trade costs exogenously into the model generates greater variation in price dispersion, but reduces the average price dispersion. Combining good specific trade costs with distribution margins computed from consumption expenditure data enables the model to match the average price dispersion exactly and generate about 48 per cent of the variation in price dispersion.

One feature of the data which has not been explored in this paper is national price discrimination by imperfectly competitive firms, or "pricing-to-market". Allowing for variable markups over marginal costs may help to explain the large unaccounted for portion of the variation in price dispersion. In the presence of a distribution sector markups - and hence prices - will also be affected by the market structure in the distribution sector, and by the vertical market structure between the producers and the retailers of goods. I leave a study of these factors to future research.

10 Appendix A

The price data complied by Crucini et al. (2005) comes from four Eurostat surveys of retail prices in the capital cities of EU countries for each of the years 1975, 1980, 1985 and 1990. Across the surveys the goods maintain a high degree of comparability, across both locations and time. The retail price of a good in a given country is the average of surveyed prices across different sales points within the capital city of that country. In total, there are 13 countries in the sample - Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and United Kingdom. However, the 1975 survey covers nine EU countries. Greece, Portugal, and Spain were added in 1980. Austria was added in 1985.

The raw data has substantial number of missing observations, which tend to increase over time because of inclusion of lower income countries that tend to consume fewer items of the survey's set of goods. Furthermore, Belgium has the least number of missing observations in every year, and Ireland has the most, except in 1990 in which case United Kingdom has the most missing observations. From the raw data, the authors eliminate any good that has insufficient number of cross-country observations, which they define as four in 1975, five in 1980, and six in 1985 and 1990. The increments are due to addition of new countries over time. Furthermore, in order to control for measurement error, goods for which the common currency price differs from the good-specific median by a factor of five or more are also eliminated. A substantial fraction of goods are labeled as "branded goods", which enhances the comparability of goods. The table below, reproduced from Crucini et al. (2005), gives the details of the raw data and the data after eliminating goods with insufficient data points and outliers.

Table 9: Scope of the Price Surveys

	1975	1980	1985	1990
Panel A: Raw Survey Data				
Number of countries	9	12	13	13
Number of goods	658	1090	1805	1896
Proportion missing	13%	36%	38%	44%
Least missing	9%	23%	25%	32%
Most missing	27%	47%	53%	55%
Proportion of branded goods	31%	42%	48%	54%
Panel B: After Eliminating goods with insufficient data and outliers				
Number of countries	9	12	13	13
Number of goods	594	686	1164	1101
Proportion missing	10%	17%	19%	23%
Least missing	4%	3%	7%	9%
Most missing	22%	28%	37%	34%
Proportion of branded goods	31%	28%	33%	38%

11 Appendix B

11.1 Data on Gross Output and Value Added

The data used to compute the share of value added in gross output of the three sectors come from the OECD STAN Structural Analysis database (STAN Industry, ISIC Rev. 2 Vol 1998 release 01). Ratio of value added and gross output is calculated for each country in each sector (traded goods sector, distribution services and non-traded good sector) for three years - 1995, 1996 and 1997, and then averaged over these years to remove any idiosyncrasies associated with the year 1996. The ratios are then averaged across countries for each sector. Australia and Ireland are not included in this exercise because of missing data on gross output. The share of traded goods sector in GDP is calculated as the value added in traded good sector as a ratio of total value added in a country, and then averaged across countries. The share of non-traded good sector in GDP is computed in the same manner. Again, both ratios are averages for the period 1995-1997.

11.2 Bilateral Trade Data and Expenditure Shares

Data on bilateral trade volumes for the 22 OECD countries are obtained from the NBER-United Nations Trade Data, 1962-2000. Feenstra et al. (2005) provide the documentation for the data. The data are organized by the 4 digit Standard International Trade Classification, revision 2. Summing the exports of a country across all trading partners gives the country's total exports. Using the OECD STAN database, gross output of the traded goods sector for the year 1996 is obtained by adding gross output of the sub sectors. Gross output is expressed in nominal local currency units. Nominal yearly exchange rates with respect to the U.S. dollar for the year 1996 are used to convert local currency units into U.S. dollars. Data on nominal exchange rates come from OECD Economic Outlook, June, 2003, Annex Table 37. Subtracting total exports of a country from its gross output gives each country's home purchases. Adding home purchases and total imports of a country gives the country's total expenditure on traded goods. Normalizing home purchases and imports of an importing country from its trading partners by the importer's total expenditure on traded goods creates expenditure shares that are used in the model.

The data on distance, border and language used in the estimation of trade costs comes from Centre D'Etudes Prospectives Et D'Informations Internationales (http://www.cpeii.fr).

11.3 Labor Force and Capital-Labor Ratio

Capital-labor ratio data and data on labor force for 1996 come from Caselli (2005), and are based on Heston et al. (2002). Since data for Germany are missing, capital-labor ratio is computed as an average of capital-labor ratios of other countries. Missing data on labor force were replaced by data from World Development Indicators (WDI).

11.4 Basic Price Value of Traded Goods as a ratio of Purchaser Price Value of Traded Goods

ϑ_i is computed from the data as 1 minus the ratio of basic price value of all traded goods and purchaser price value of all traded goods. These data are taken from the use tables of the countries. The basic price value of all traded goods is calculated as the sum of the supply of the 29 categories of goods valued in basic prices. The purchaser price value of all traded goods is calculated analogously. Since data for Canada, Mexico and Switzerland are not available, ϑ for these countries is assumed to be the average of ϑs of the remaining 19 countries.

12 Appendix C

Table 10: Parameters

Parameter	Description	Value	Source
	Panel A: Ricardian Model		
θ	controls heterogeneity in productivities	0.15	Alvarez and Lucas (2007)
η	elasticity of substitution	2	Alvarez and Lucas (2007)
β	share of value added in gross output of traded goods	0.36	OECD STAN (Avg. 1995-1997)
$1-\rho$	share of traded good sector in GDP	0.25	OECD STAN (Avg. 1995-1997)
α	share of capital in GDP	0.33	Gollin (2002)
τ_{ij}	bilateral trade cost		estimated from gravity equation
λ_i	absolute advantage in traded goods		match share of country in its own expenditure on traded goods
	Panel B: Ricardian Model with Distribution Costs		
θ	Same as in the Ricardian Model		
η	Same as in the Ricardian Model		
β	Same as in the Ricardian Model		
α	Same as in the Ricardian Model		
τ_{ij}	Same as in the Ricardian Model		
λ_i	Same as in the Ricardian Model		
δ	share of value added in gross output of distribution service	0.58	OECD STAN (Avg. 1995-1997)
γ	share of value added in gross output of non-traded good	0.62	OECD STAN (Avg. 1995-1997)
$1-\mu$	share of non-traded good in GDP	0.58	OECD STAN (Avg. 1995-1997)

Table 10: (continued)

Parameter	Description	Value	Source
ν	controls heterogeneity in distribution services	0.75	match average of country standard deviations of distribution margins
ζ_i	controls country's efficiency in distribution services		match average of distribution margins of all goods in country

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