Trade Costs: An empirical assessment based on Law-of-One Price deviations and the Direction of Trade*

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Abstract

The importance of trade costs in segmenting product markets cannot be captured by considering aggregate prices or in the absence of information on the direction of trade. We address this problem by utilizing product-specific prices along with cross-sectional productivity measures and bilateral trade flows that allow us to identify the probable source of any one product. We show that trade costs in the form of transportation and distribution costs are important in determining international price differences and segmenting international markets. Physical distance relative to the origin has a precisely estimated positive impact on international deviations from the Law-of-One-Price that is larger than estimates that do not account for the origin of each product. Based on our benchmark estimate, the price elasticity of distance is as high as ten percent.

Keywords: microeconomic data, law-of-one-price, trade costs, market segmentation.

JEL Classification: F4

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1. Introduction

Crucini, Telmer, and Zachariadis (2005) (CTZ) make the case that the Law-of-One-Price (LOP) and Purchasing Power Parity (PPP) are essentially about the cross-sectional distribution of international relative prices rather than the time-series behavior of changes in these, and that "economic theory places much starker restrictions on LOP deviations than on their changes." This implies that to close the gap between theory and empirics one needs microeconomic price levels that enable exact comparisons across space. In line with this, Anderson and van Wincoop (2004) propose the use of price levels comparable across locations at a point in time as a promising route for inferring trade costs, arguing "*i*t is hard to see how information can be extracted about the level of trade costs from evidence on changes in relative prices." In addition, they suggest that to infer trade cost levels from prices "[*a*] natural strategy would be to identify the source country for each product," since "[*u*]nfortunately survey data often do not tell us which country produced the good."

In this paper, we use *microeconomic price levels* along with cross-sectional productivity indices and bilateral trade flows between countries to identify the likely source of each product. We then examine an empirical model where international price dispersion is determined by *transport costs*, local trade costs, taxes, and market size. Trade costs in the form of transportation and distribution costs are shown to be important in segmenting international markets.

Transport costs and broader trade costs are of central importance in many macroeconomic models, as in the recent examples of Bergin and Glick (2003) and Atkeson and Burstein (2007, 2009). However, assessing these at the macroeconomic level has proved problematic. Anderson and van Wincoop (2004) argue persuasively that "average price dispersion measures are not very informative about trade costs." In general, the impact of trade costs in segmenting individual product markets will be underestimated when considering aggregate prices or the average (over products) of price deviations. This is the case since countries are likely to both export and import some of the different goods that go into the construction of the aggregate or average composite price. As a result, the impact of transport costs on price differences would wash out on average even if these were important in segmenting markets as determinants of international price deviations for individual products. This is the "*averaging-out property*" put forth by Crucini, Telmer, and Zachariadis (2004).

Trade costs will also be mismeasured if the distance between two locations does not capture distance between exporter and importer. For example, if trade between two countries does not occur for a product, then that price difference will lie between the no-arbitrage bounds and will be less than the trade cost. On the other hand, if both countries export the product to each other, the overall impact of trade costs on that product's price difference between the two locations can be zero even if these costs are large. In fact, a bilateral price difference reflects the size of trade costs only when one of the locations is the source of the product to the other. Thus, even when prices of individual products are available across international locations, trade costs can be mismeasured when the source of the product being compared across locations is not accounted for. This might be behind the small or non-existent estimated impact of physical distance on deviations from LOP often found in the literature.

Using actual retail prices from the Economist Intelligence Unit, Anderson and Smith (2004) estimate price elasticities with respect to distance of 0.012 for the overall sample of countries and 0.006 for price comparisons within North America. Looking at particular countries, the price elasticities become negative, with estimates of -0.005 for the US and -0.017 for Canada.[1] Engel, Rogers and Wang (2003) estimate higher price elasticities with respect to distance using US-Canada actual retail price data. They consider *absolute* deviations from LOP which alleviates the "averaging-out" problem. Their estimate for distance in the full panel of 100 items is 0.00321, and estimates range from 0.00584 for "Food items" down to -0.00004 for the category "Miscellaneous Products".[2]

Our paper is closer in spirit to Ceglowski (2003). The latter author takes a first step towards addressing the above concerns by considering relative distance from a "core location" (*assumed* to be Toronto) *in addition to* intercity distance. Using actual retail prices for 45 consumer goods across 25 Canadian cities, Ceglowski (2003) explains *absolute* log deviations from LOP within Canada.[3]

[1] Their dependent variable is the log deviation from LOP, $\ln(e_{jkt}p_{ijt}/p_{ikt})$, considered for all goods i and all possible $j-k$ bilateral comparisons in every period t. We report their estimates from Table 2 for the case of tradeable goods. The specific country results are from their Table 3.

[2] These estimates are reported in Tables 2A, 3A and 4A respectively of Engel, Rogers and Wang (2003).

[3] In addition to *absolute* values of LOP deviations, she considers log deviations from LOP relative to Toronto. This allows inclusion of "information contained in the *sign* of the price differentials" (p.395), which is useful since for comparisons relative to the exporting location this *sign* contains information about the *direction of trade* and can identify trade cost levels. She shows in Table B1 that distance relative to the *core* has a significant positive relation with price differentials for over half of the products, consistent with distance from the *core* capturing transport costs. The estimated coefficient of relative distance is negative for several other products, suggesting that using a single core location as the origin of all products is not sufficient to capture the level of transport costs.

In adding distance from a "core location", this author allows for the fact that "[*g*]eography could play an additional role in price differentials when prices include freight costs from a central or core location" since "[*i*]f shipping costs are a positive function of distance, this possibility implies a city's prices would be higher the further it is from the core location." The estimated coefficient is positive and significant for about half of the products[4]. The author concludes that the "analysis uncovers a positive link between relative distances from a core location and price disparities, suggesting that the price effects of distance may not be fully captured by simple intercity measures."

We attempt to resolve the concerns raised in the previous paragraphs by utilizing product-specific price differences[5] and identifying core locations that differ across types of goods. To identify *the* most likely source for each product, we use information on the productivity of each country in each industry. As an alternative identification strategy, we use realized trade flows to determine the price of the product in the probable source as a weighted average price of an importing country's actual trading partners. Utilizing the unique (in terms of breadth of the goods covered and exact comparability across locations) microeconomic dataset of price levels across the EU from CTZ, along with information on the *direction of trade*, we identify economically meaningful measures of trade costs in general and transport costs in particular through their estimated impact on product-specific retail price differences between importing and source countries.

Trade across these EU countries is less likely to be characterized by high policy-related and other unidentified trade barriers, allowing geographic distance to better capture transport costs. Thus, we use geographic *distance* to measure transport costs. To account for local trade costs, we consider real income per capita and industry-specific features of local costs as captured by the real wage rate. We find that transport costs measured by geographic distance are important in explaining deviations from LOP, with estimated price elasticities with respect to distance as high as ten percent. To the extent that transport costs are relatively less important across these European countries, our estimates can be seen as a lower bound for average transport costs characterizing world trade. Overall, the data are consistent with transport costs and local trade costs playing

[4] See her table 4, specification 3.

[5] Earlier work utilizing microeconomic price levels includes Parsley and Wei (1996, 2001). However, the focus of these papers in on the variability of LOP log deviations over time (as in the seminal work of Engel and Rogers, 1996, who however consider more aggregate data), so that their estimates of distance coefficients are not directly comparable to estimates in the literature focusing on price dispersion across space.

important roles in the determination of international retail price differences.

The remainder of the paper is organized as follows. Section 2 offers some motivation behind our empirical application. Section 3 describes the price data and the construction of cross-sectional total factor productivity (TFP) indices and trade-weighted relative prices. Section 4 reports the main results of our estimation exercise, and section 5 briefly concludes.

2. Motivation

If one can identify the source of each product then one can capture the exact level of trade costs using differences in price levels. This is in line with what we do in this paper and with Anderson and van Wincoop (2004) who suggest the use of actual price data comparable across locations at a point in time as a promising route for extracting information about trade cost levels. Initially abstracting from markups and taxes, they impose arbitrage constraints and derive an inequality that constrains international relative prices. If country j buys from country κ then it pays a price $p_j = c_\kappa \tau_{j\kappa}$, where c_κ is the cost of production in κ and $\tau_{j\kappa}$ is the trade cost of transporting the good from κ to j. Country j buys from κ if $c_\kappa \tau_{j\kappa}$ is the lowest among all potential sources. The inequality for any two importing countries j and k is $\frac{c_{z_j}\tau_{jz_j}}{c_{z_j}\tau_{kz_j}} \leq \frac{p_j}{p_k} \leq \frac{c_{z_k}\tau_{jz_k}}{c_{z_k}\tau_{kz_k}}$, where p_j and p_k are retail prices in countries j and k, and z_j and z_k are the optimal sources for countries j and k respectively. When countries j and k purchase the good from the same source, κ, then the above inequality reduces to $\frac{p_j}{p_k} = \frac{\tau_{j\kappa}}{\tau_{k\kappa}}$, with the relative price tied down by trade barriers. Anderson and van Wincoop (2004) conclude that when κ is one of the two countries "the relative price captures exactly what we intend to measure" as $\frac{p_j}{p_\kappa} = \frac{\tau_{j\kappa}}{\tau_{\kappa\kappa}} = \tau_{j\kappa}$, the trade cost between destination j and source κ.

We utilize independent information on the productivity of each country in each industry to identify the most likely source for each product. This is consistent with the above framework where a country buys from the cheapest source, and with the models of Eaton and Kortum (2002) and Bernard, Eaton, Jensen, and Kortum (2003), where the most productive country for any one product is the sole source of that product to the rest of the world. Alternatively, we consider actual trade flows to construct the price in the source, κ, as a weighted average of each country's within-sample trading partners.

Under the maintained assumptions above, the relative price thus obtained could be attributed to trade costs. However, controlling for a number of additional potentially important determinants of international price differences is necessary in practice if we are to best isolate the impact of trade costs. Our point of departure is the framework outlined in Anderson and van Wincoop (2004), where final goods prices might differ internationally to the extent that transport costs, local trade costs, taxes, and markups exhibit variation across countries and goods.

Given the absence of direct measures of transportation costs for broad cross sections of goods and countries[6], we follow the usual practice of using physical distance between the capital cities of the countries in our sample to capture transportation costs.[7] That is, once we identify the probable source for each product, we identify the size of transport costs by the estimated coefficient of distance from the source country.

We also account for the presence of local distribution costs through income per capita differences and by considering industry-specific features of these local costs as captured by domestic real wage rates. Industry-level real wage rates capture the local cost component attributed to labor specific to each industry. That our wage measure captures variation across both industries and countries is an advantage relative to country-specific measures of local costs. However, since countries with higher GDP per capita typically have higher wage rates and other local costs (e.g. rent), GDP per capita can be used as an alternative measure of the local cost component of trade costs.

To capture market size, we utilize population size at the level of the country or, where available, at the level of the city. Market size can be a measure of the markup if one assumes larger markets are more competitive so that demand elasticities are higher and markups lower there. This would be consistent with the theoretical model of Melitz and Ottaviano (2005) who show that “larger markets exhibit tougher competition resulting in lower average markups”, and with the empirical findings of Campbell and Hopenhayn (2005) who find that larger markets are more competitive for most industries, with a doubling of the number of competitors in a market decreasing markups by at least that much in a sample of industries across 225 U.S. cities. In general, larger markets

[6] See Hummels (1999), for an approach that incorporates direct measures of transport costs utilizing freight data for a small group of importing countries.

[7] Disdier and Head’s (2008) summary of findings in the literature suggests an inversely proportional relationship between trade and distance. Although other factors might also be important, this relation should at least in part be attributed to trade costs increasing with distance.

are likely to have a greater number of exporters serving them -in the presence of some fixed cost component in trade costs- and are also more likely to have domestic production of close substitutes for imports -in the presence of some fixed cost component to production that induces economies of scale- both factors leading to a more elastic perceived demand for imports and lower prices in large markets. It might also be that potentially price-discriminating exporters value large foreign markets more than small ones, exhibiting greater risk aversion for losing large markets, and are thus less likely to have higher markups there in the presence of demand uncertainty.

An alternative starting assumption would be that markups are of similar level across countries so that they do not affect international price differences.[8] In this case, coefficients for population size differences could be measuring scale economies common across industries and specific to countries. That is, population size might be capturing scale economies that lower average domestic production or distribution costs leading to lower domestic prices in larger countries. Since the scale of domestic production depends on exports, population size is less likely to capture scale economies from the production side and more likely to capture scale economies in domestic distribution and retail.

Differences in taxes are also likely to be important in determining deviations from LOP across countries. These are captured by VAT rates that differ across types of goods and countries. Finally, recognizing that none of our explanatory variables are available at the individual good level, we introduce good-specific fixed effects aiming to capture factors specific to individual goods that affect deviations from LOP but are not captured by the other included explanatory variables.

3. Data Construction and Methodology

We now describe the diverse data we have put together from a number of different sources. This labor-intensive task involves a concordance that allocates individual consumption goods for which prices are available, into industries for which our explanatory variables are available. We also describe the construction of variables to be used in the empirical analysis. This involves the creation of novel empirical concepts as explained in detail below.

Denoting p_{ij} as the local currency price of good i in country j, p_{ik} as the local price of the same good in country k, and e_{jk} as the nominal exchange rate of country j in terms of currency units of

[8] This is discussed in Anderson and van Wincoop (2004) and imposed in Crucini, Telmer, and Zachariadis (2004).

country k, we define log LOP deviations as

$$\ln q_{ijk} = \ln(e_{jk}p_{ij}/p_{ik})$$

The retail price data utilized here are the same as that used in CTZ.[9] These data originates from Eurostat surveys conducted across European cities sampled at five year intervals between 1975 and 1990. A detailed description of the data is provided in CTZ and a comprehensive list of the goods is available at http://bertha.tepper.cmu.edu/eurostat. The level of detail can best be seen through a couple of typical examples of item descriptions included in this dataset such us: 500 grams of long-grained rice in carton, or racing bicycle selected brand. As evident in the latter example, the level of detail goes down to the level of the same brand sampled across locations. This enables exact comparisons across space at a given point in time. The price data for each cross-section is collected in a sequence of surveys where the same group of goods are collected within the same period for all countries.[10] The Eurostat survey covers 9 countries for 658 goods in 1975, 12 countries for 1090 goods in 1980, and 13 countries for 1805 and 1896 goods respectively for 1985 and 1990. The nine EU countries in 1975 are Belgium, Denmark, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, and the UK. Greece, Portugal and Spain are added in 1980, and Austria in 1985. Goods were allocated into a three-digit industry in order to be matched with the industry-specific measure of the real wage rate, as well as to TFP and bilateral import flows the construction of which is discussed in the next few paragraphs.

The distance measure we use is the great-circle distance between airports of the capital cities measured in kilometers. The capital city of each country is the sampling location of the price data for all countries but Germany for which reported prices are an average from a number of cities within that country. Thus, for Germany we use distance relative to Frankfurt which is a transportation center for that country. Real GDP per capita and population are obtained from PWT 6.1 for each country and each of the four cross-sections. We use the constant price chain series

[9] We use the common currency prices with the outliers having being removed as in CTZ. CTZ remove the price entry for a good in a certain country when the price in that country differs by a factor of five from the average common currency price for that good across countries.

[10] In what CTZ call '1985,' for instance, the prices of most services were collected in September-October 1985, while prices of most clothing items were collected in December of 1984. The nominal exchange rate data with which prices were converted into a common currency takes explicit account of this timing, taking the form of averages of daily data over the relevant time intervals.

GDP per capita. We were also able to obtain total resident population for each capital city (Vienna, Brussels, Copenhagen, Madrid, Paris, London, Athens, Dublin, Rome, Amsterdam, and Lisbon) for 1991, from the Urban Audit dataset available at http://www.urbanaudit.org/DataAccessed.aspx. In the case of Germany, we use the average populations for five cities: Frankfurt, Berlin, Dusseldorf, Hamburg, and Munich.

We also use data on VAT rates for 23 different categories of goods and services for all countries in our sample in 1990. For 1975, 1980, and 1985 VAT is not observed for Greece which entered the European Community (EC) in 1980, and for Portugal, and Spain which entered the EC in 1985. This is the same VAT data as in CTZ, assembled from the European Commission publication "VAT rates applied in the member states of the European Community" (2002) and other sources.

Data required for TFP calculation come from two World Bank sources: the Trade and Production Database, and the Database on Investment and Capital for Agriculture and Manufacturing. The Trade and Production Database makes available production and trade information for 100 developing and developed countries for the period 1976 to 2004, collected from different sources and merged into a common classification. The main source for its production data is the UNIDO and OECD joint collection program. We use value added in current dollars, fixed capital formation, wages and salaries, and the number of employees for 28 three digit manufacturing industries. Value added in current dollars is deflated to obtain value added in constant dollars using price deflators from the OECD STAN database. Wages in current dollars were deflated using these same price deflators to obtain wages in constant dollars. The real wage rate utilized in the regressions was constructed as wages and salaries in constant dollars over the number of employees.

The Database on Investment and Capital for Agriculture and Manufacturing, reports the total capital stock for the manufacturing sector. We calculate total manufacturing sector investment, using capital formation data for 28 manufacturing industries from the Trade and Production Database. We then construct each industry's investment share in total manufacturing for each country. Finally, we assume that the share of investment for the industry in total manufacturing for a specific year is equal to its share of the capital stock, and use this observed industry share and total manufacturing capital stock to calculate capital stock for each manufacturing industry.

With the data at hand and under the assumption of a Cobb-Douglas production function, TFP between countries j and k for industry h is constructed following Harrigan (1997) as

$$TFP_{hjk} = (Y_{hj}/Y_{hk})(L_{hk}/L_{hj})^s(K_{hk}/K_{hj})^{1-s}$$

where Y denotes real value added, L is the number of employees, K is the capital stock for each industry and s is the average share of labor in total cost between j and k. In calculating TFP, we use three-year averages of the variables using the two preceding years along with each cross-section's sampling year. The data for constructing TFP is not available to us for 1975 and is only available for five of the above countries in 1980 limiting our ability to identify the source country. This is the reason why for regressions that utilize TFP information, we consider only 1985 and 1990 for which TFP can be constructed for the following nine countries: Austria, Denmark, Germany, Greece, Ireland, Italy, Portugal, the Netherlands, and the UK. The availability of the TFP measure across industries is reported in Table A1.

Throughout the paper, we consider manufacturing goods prices since we do not have disaggregate data for constructing TFP across industries of the service sector. Excluding services industries is not necessarily a handicap of the analysis as we are primarily interested in transport costs faced by traded goods. As shown in arbitrage models (see, for example, Lee 2004), price differences across countries will equal the trade cost for products that are traded, while endowment or productivity differences determine the degree of LOP deviations for products that are not traded in equilibrium.

To identify the probability-weighted source for each good sold in each country of the Eurostat price dataset, we utilize bilateral trade flows from the OECD *International Trade by Commodity Statistics* (ITCS) database. The ITCS database includes annual bilateral flows in current $US between 269 international locations for 2581 goods categories at different levels of aggregation for the period 1960-2000. Using bilateral trade flows instead of TFP for identifying the source for each product enables us to use the full sample of countries and years allowed by the Eurostat price data, with the exception of Luxembourg. Utilizing this broader sample of countries is desirable as it enhances our ability to assess probable source for each product among a broader group of possible origin countries. Having inspected the list of 2581 traded goods categories, we came up with a list of 68 aggregate product categories chosen to best relate to the products from the Eurostat price data. These 68 categories which are described in the first column of table A2, were then aggregated by ISIC code into 42 separate 4-digit categories of the manufacturing sector, shown in the second column of Table A2, that are finally mapped onto the disaggregated product prices from the Eurostat data.[11] We end up with imports for each of 42 industries of each country in our sample from each other.[12] That is, we consider imports of country j from each of the other countries in our Eurostat price data for each industry h. For each importer j and industry h, the probability-weighted source price for a specific product is defined as the weighted average of the prices of exporters of that product with weights calculated using bilateral trade flows.

Denoting im_{jkt}^{h} as imports of country j from country k for industry h in cross-section t, the weight of exporter country k for importer j in industry h is defined as $w_{jkt}^{h} = im_{jkt}^{h} / \sum_{k=1}^{n-1} im_{jkt}^{h}$, where n is the number of countries in sample. However, some exporting countries have missing prices for some goods so that the sum of the above weights would not add up to one in these cases. To cope with this, we re-scale the weights.[13] The price in the probability-weighted origin is then simply given by the weighted sum of exporting countries' observed prices:

$$p_{j\kappa t}^{h} = \sum_{k=1}^{n-1} w\_new_{jkt}^{h} * p_{kt}^{h}$$

where we have one probability-weighted source, κ, for each importer j in each industry h. We can then compare the price of each product sold in the importing location relative to this probability-weighted source. The same weights are used in order to construct real GDP per capita, the real wage rate, and population size for the probability-weighted origin relative to which we compare the respective variables of the importing country. Physical distance for each importer is also constructed relative to this probability-weighted origin.[14]

[11] There is a "many-to-one mapping" from product prices to 4-digit industry categories in the trade data. Future work should focus on disaggregated trade data that can be matched to products in the price surveys.

[12] As we are constrained by the number of countries for which we have price data, we actually use eight countries for 1975, eleven for 1980, and twelve for 1985 and 1990. We note that while in the price data, Belgium and Luxembourg prices are given seperately, the bilateral flows dataset includes the aggregate of Belgium and Luxembourg reducing the number of countries we can consider by one for each cross-section.

[13] For each good, we consider only imports from countries for which the price is observed so that the new weights $w\_new_{jkt}^{h}$ are given by multiplying w_{jkt}^{h} by $\sum_{k=1}^{n-1} im_{jkt}^{h}$ over the new imports sum.

[14] Since the probability-weighted source differs for different types of products (different industries), then relative distance for each importer relative to the source, used in our regression framework in this case, actually varies both across industries and countries.

4. Estimation and Results

Based on the framework discussed in section 2, price differences between importing and source locations for each product are determined by transport costs and international differences in local distribution costs, taxes, and market size. We consider the following regression equation

$$q_{ijk} = a_0 + a_1 Dist_{jk} + a_2 y_{hjk} + a_3 Pop_{jk} + a_4 VAT_{hjk} + a_i + \varepsilon_{ijk} \tag{4.1}$$

where q_{ijk} is the log deviation from LOP for good i between countries j and k, a_0 is a constant term, and ε_{ijk} is an idiosyncratic disturbance. $Dist_{jk}$ is the (log) distance separating the capital cities of the two countries and proxies for transport costs impeding trade and maintaining price differentials across j and k. The variable y_{hjk} is the log difference in real wage rates between j and k for industry h and captures the local (distribution) cost component suggested by the theoretical framework from CTZ and Anderson and van Wincoop (2004). That is, it measures cross-country differences in the wage component of local distribution costs in each industry h, where h denotes a three-digit industry classification with a one-to-many mapping into individual goods i. In some specifications, we use real GDP per capita for each country as an alternative measure of local distribution costs. Pop_{jk} is the log difference in population size in 000's between locations j and k and is meant to capture the effect of domestic market size. The inclusion of population size is consistent with standard gravity models. VAT_{hjk} is the log difference in VAT rates that differ across types of goods and countries. Finally, the individual effect a_i will be treated as a random effect or a fixed effect for good i that does not vary across bilateral comparisons.

We estimate this first as a random effects model using GLS, consistent with Moulton (1986), to take care of disturbances that are correlated within groups. Methods used to measure the effect of aggregate variables on micro units that are based on the assumption of independent disturbances are not appropriate for data from populations with grouped structure. It is reasonable to expect that units sharing an observable characteristic may also share unobservable characteristics that would lead to correlated regression disturbances. Even if this correlation is small, applying OLS would lead to standard errors that are biased downward and to spurious findings of statistical significance for the aggregate variable. Thus, Moulton (1986) suggests instead using a GLS random effects approach that alleviates this problem.[15]

Even though the Hausman test usually favors random effects over fixed effects, we also estimate and report results based on a fixed effects model. This can be desirable for a couple of reasons. First, given the absence of explanatory variables that vary across goods, incorporating good-specific fixed effects is the sole way of introducing a good-specific explanatory variable to alleviate the omitted variables problem. Adding these good-specific fixed effects, thus acts as a robustness check to the inclusion of an otherwise omitted explanatory variable, for the coefficient estimates of our other explanatory variables which have no variation across goods. A second reason for including good-specific fixed effects, is that this model allows for and is therefore robust to arbitrary correlation between the unobserved effect a_i and the observed explanatory variables $Dist_{jk}$, y_{hjk}, Pop_{jk}, and VAT_{hjk}.[16]

Initially, equation (4.1) is estimated for *all* possible *unique* bilateral price comparisons *j*-*k* (similar to what is done in much of the literature) with each bilateral comparison made according to alphabetical order rather than relative to countries more likely to be the source of a product. In this case, the *sign of the price differentials* will not be informative about the *direction of trade* as price comparisons are not made relative to the exporting location. This would then render meaningless the coefficient of geographic distance as a proxy for transport costs. Estimation using all bilateral comparisons is undertaken here as a mere reference point with which to compare the distance coefficient estimates we will obtain once we utilize information on the probable source of each product. The random effects estimate for the price elasticity with respect to distance is 0.0454 and significant at the one percent level in 1985, and 0.0016 and statistically indistinguishable from zero in 1990, in specifications with the wage rate included.[17] These estimates are devoid of meaning as distance between two arbitrary countries does not necessarily capture distance between exporter and importer. Again, if trade between two countries does not occur for a product, then that price difference lies between the no-arbitrage bounds and is less than the trade cost. It is also possible

[15] Estimating random effects for individual goods makes more sense here than random effects for industries or countries, since the a_i are less likely to be correlated with the explanatory variables ($Dist_{jk}$, y_{hjk}, Pop_{jk}, VAT_{hjk}) as compared to individual effects for industries h or countries j, k.

[16] In our treatment and use of random and fixed effects models, we have benefitted from the discussions in Moulton (1986), Wooldridge (2002, p. 251-252), and Petersen (forthcoming, p.28-30).

[17] The fixed effect estimates are 0.044 and 0.00096 in 1985 and 1990 respectively. Including GDP per capita instead of the wage rate, the corresponding random effects estimates for distance are 0.0577 and 0.0002, while the fixed effects estimates are 0.0553 and −0.0009. In all cases, the estimates for 1990 are statistically insignificant.

that both countries being compared export the same product to each other. To the extent that this is the case, the final price for these products incorporates a similar transportation cost in both countries so that there might be little or no impact of transportation costs on price differences for these products between the two countries. Moreover, considering all possible bilateral comparisons tends to average out around zero the estimated impact of transportation costs on prices.[18] Thus, this should be viewed as a straw man to act as a reference point with which to compare distance coefficient estimates that utilize information on the direction of trade.

Utilizing information on relative productivity

In general, in the absence of some information regarding the *direction of trade*, the distance coefficient cannot capture transport costs well in the context of "directional regressions" such us those estimated for equation (4.1) above. Considering LOP deviations as in equation (4.1), rather than their absolute values, allows us "to include the information contained in the sign of the price differentials" (Ceglowski, 2003, p.395), in accord with the premise that distance from the source captures transport costs. However, the *sign of the price differentials* contains information about the *direction of trade* only when price comparisons are made relative to the exporting location. This is why Anderson and van Wincoop (2004) argue that to estimate the precise role of *trade costs* in determining differences in price levels for a good between locations, we would need to identify the source of that good.

A way to address the problem of identifying the exporting country, is to assume the *most* productive country in the sample exports the good to others, in line with the theoretical models of Eaton and Kortum (2002) and Anderson and van Wincoop (2004).[19] Thus, we first rank

[18] It is possible that k is the main exporter to j for some product i and does not import this from j, and that j is the main exporter to k for some product i' and does not import this from k. The overall result is a possible washing out of the effect of transport costs across goods for an aggregate or average measure of prices, related to the "averaging-out" property discussed in Crucini, Telmer, and Zachariadis (2004), and can be addressed by using absolute price differences or an appropriate variance measure for each product across countries.

[19] An other way to address the problem discussed above is to assume that the *more* productive among any two countries being compared will export the good to the other. A problem with this is that, given measurement error associated with TFP construction, comparing countries with similar productivity is likely to give the wrong ordering more often than when considering price comparisons relative to the *most* productive country in the data. The latter is preferable as it avoids ordering countries based on comparisons among countries that are closer together in tems of productivity. Yet an other approach would be to assume one of the locations to be the main exporter using a-priori information, similar to the assumption of Ceglowski (2003) that Toronto is the core location. However, estimation results using Germany or the U.K. as the core location for all goods, suggest that both the sign and significance of distance coefficients are not robust across periods or reference countries.

countries according to their productivity in each industry and then denote the *most* productive country to be the *source* or reference country for that specific industry. Under the assumption that the most productive country for a certain industry will be the main exporter of goods of that industry, we construct good-specific log relative prices between each country j relative to the main exporter country κ for each industry h. As we show next, this methodology goes some distance into identifying the source country, providing improved estimates for transport costs.[20]

Next, we consider regression equation (4.1) to explain $q_{ij\kappa}$, the log deviation from LOP for good i between country j and κ, where κ is now the most productive country in industry h assumed to be the main source for product i in country j. We construct the dependent variable of prices relative to the most productive location, using the industry-specific country ranking implied by cross-sectional TFP levels. $\text{Pop}_{j\kappa}$ and $\text{y}_{hj\kappa}$ are population and real wage rate or GDP per capita log differences between country j and origin country κ. $VAT_{hj\kappa}$ is the log difference in VAT rates between importer j and source κ for each type of good. $\text{Dist}_{j\kappa}$ denotes log distance between source κ and destination j. Our specification incorporates information regarding the direction of trade and can thus help assess the overall level of trade costs and the transport cost component of these implied by the estimated coefficient for physical distance. Results from this estimation framework are summarized in Table 1. Random effects estimates are reported in columns (1), (3), (5), and (7) while fixed effects estimates are reported in columns (2), (4), (6), and (8).

Distance from the origin has a positive and significant impact on international price differences, suggesting a role for transportation costs as a determinant of these. Based on 1985 random effects estimates, doubling distance increases prices by 10.3 percent as reported in column (3) of Table 1, more than twice the coefficient estimate of 4.5 percent for the specification with all unique bilateral price comparisons (not shown in the Tables). The improvement in terms of the estimated price elasticity with respect to distance is even more striking for 1990. This changes from 0.0016 and statistically indistinguishable from zero using all bilateral comparisons, to 0.078 and strongly significant as shown in column (7) once we account for the probable source of products. The

[20] Before turning to estimation using price differences relative to the most productive country, we evaluate the hypothesis that productivity is inversely related to prices, consistent with productivity being a determinant of the direction of trade. Estimating (4.1) with an added term for total factor productivity differences, TFP_{hjk}, across countries for each three-digit industry h (using random effects and including the wage rate), the elasticity of price differences with respect to TFP_{hjk} is $-.039$ for 1985 and $-.071$ for 1990, both statistically significant beyond the one percent level. The respective fixed effects estimates are $-.044$ and $-.071$ and strongly significant.

estimated elasticities discussed here refer to specifications that include the wage rate. However, the estimates and inferences are similar when we consider specifications that include GDP per capita instead of the wage rate as a measure of local costs, or specifications that use fixed effects instead of random effects. For example, fixed effect estimates which are preferred based on the Hausman test for 1990, imply an estimated price elasticity with respect to distance that is equal to 10.8 percent when including GDP per capita as shown in column (6), and 9.8 percent when including wage rates instead as reported in column (8). We conclude that when the most productive country for each industry is chosen as the reference location, distance consistently has a positive and significant effect on relative price levels. As the distance between source and destination country increases, transport costs go up and so does the price of the good in the destination country. Our approach goes some distance in capturing the likely source country for each industry, even if the existence of multiple products within any industry creates aggregation bias that might still wash out the impact of transport costs to a considerable degree.[21]

Local costs appear to have strong effects on price differences, with elasticities equal to 11.3 percent for 1985 and 17 percent for 1990, as reported in columns (3) and (7) of Table 1 respectively, for specifications that include the real wage rate in a random effects regression model. We note that the coefficient estimates more than double when we use country-specific measures of GDP per capita to measure local costs, as can be seen by looking at the relevant columns of Table 1. For the same specification, population size has a negative effect on price differences with an estimated price elasticity at -3.2 percent in 1985 and -3.9 percent in 1990. The finding that higher population is associated with lower prices in a country suggests a potential role for markup differences across countries due to differences in demand elasticities that are positively related to the size of the market. Alternatively, scale economies in distribution related to domestic market size might also be behind this finding. Finally, differences in VAT rates are estimated to be very important in determining price deviations from the law-of-one-price relative to the most productive country for

[21] This approach does not fully resolve the problem of identifying the source country for each good since the measure of productivity is at the three-digit level. Moreover, for each destination country there might be more than one main exporter of goods in a certain industry and this exporter might or might not be among the countries in our sample. We begin to address these problems in the section *Utilizing Trade Flows*, where we use bilateral imports among the countries in our sample to obtain the probability that a good sold in a certain location was imported from any of the countries in the sample, and by making use of the share of imports from non-EU countries to restrict the sample to goods that are more likely to be imported from countries in our sample.

each industry in the sample. The elasticity estimates of price differences with respect to VAT rates are typically above fifty percent.

Utilizing trade flows

Assuming the most productive country in an industry to be the sole exporter of goods of that industry to countries in our sample does not completely resolve the problem of identifying the source. It is possible that a product is exported by more than one country. To cope with this, we use information about industry-specific bilateral trade flows across the countries in our sample so as to take into consideration that the same type of good can be exported by more than one country.

However, the goods could also be imports from countries outside the EU sample we have price data for. To the extent that this is the case, our within-sample import weights will not reflect the true probability that a good sold in one location is imported from an other location in the sample. Indeed, for some countries and industries, important exporters are outside the EU sample we have price data for.[22] To address this problem, the ratio of imports from the EU over total imports was constructed for each importer and industry, and if this was lower than 50 percent the good belonging to that industry was dropped from the dataset. This approach raises the likelihood that any good considered is actually imported from an EU country, so that we can better identify the source and more precisely estimate transport costs relevant to our sample of countries.

We proceed to utilize realized trade flows among the countries in our sample so as to determine the direction of trade and construct price comparisons for each product consumed in the importing country relative to countries likely to be *a source* for that product. The probability that a country in our sample is the exporter to a given destination for a good belonging to a given industry is constructed for each industry and destination as the ratio of imports from that country to the given destination over total imports to that destination. For each destination country and industry, we construct a weighted price as the sum of weighted exporting country prices where the weights are simply the ratios from above and as described in detail in the data section. Finally, the prices in the destination country are compared to this weighted sum to obtain log price differences for each good.

[22] The share of EU imports for countries in our sample in 1990 was 84 percent for "furniture except metal industries" but only 51 percent for "tobacco and tobacco product industries." The import share from the EU also varies across countries for the same industry, with the share of EU imports for France, Italy and Greece in "tobacco and tobacco product industries" in 1990 higher than 90 percent and those for Denmark and Spain 11 and 8 percent respectively.

This is the dependent variable we use now to estimate equation (4.1). Source κ is now a weighted sum of probable exporters with probabilities obtained as above. We note that the same weights are used in order to construct real GDP per capita, real wage rates, VAT rates, and population size differences for each importer relative to the probability-weighted origin. Physical distance for each importer is also constructed relative to this probability-weighted origin as $Dist_{hj\kappa}$, where this now varies both across industries and countries, since the probability-weighted source, κ, for each importer, j, differs for different types of products h.

Once again, we use GLS to estimate the empirical model given by equation (4.1). The price data have been cleansed of outliers as in CTZ. However, since using trade quantities introduces an additional source of outliers given the well known measurement problems with trade flows measures, we use a Grubbs test to identify outliers which were then expunged from the data set.

In Table 2, we report estimates from this specification. Random effects estimates are reported in columns (1), (3), (5), (7), (9), (11) and (13) while fixed effects estimates are reported in columns (2), (4), (6), (8), (10), (12) and (14). The distance coefficients are estimated precisely and always positive for 1975, 1980, 1985, and 1990. The estimated price elasticity with respect to distance is 6.5 percent in 1975 as shown in column (1) of Table 2 for the specification with GDP per capita, declining down to 1.8 percent by 1990 as reported in column (11), based on random effects estimates.[23] The impact of distance is 7.7 percent in 1975 and 5 percent in 1990 as shown in columns (2) and (12) respectively, based on fixed effects estimates. In specifications that include the wage rate as a measure of local cost, the price elasticity of distance is about 4 percent in 1980 as reported in columns (5) and (6) of Table 2, and about 3 percent in 1990 based on random effects estimation, reported in column (13). The Hausman test implies that the preferred estimate for 1990 is the one provided by the fixed effects model, and is equal to 6.9 percent and strongly significant as shown in the last column of Table 2. These estimates taken in their totality suggest that transport costs are important for the determination of international price differences. Moreover, these estimates -using actual realizations of trade flows across countries- offer a clear improvement relative to those obtained using arbitrary comparisons, and are qualitatively similar to those obtained under the

[23] An interesting feature that emerges here, is the falling importance of transport costs in absolute terms as witnessed in the declining estimated coefficient for the impact of physical distance on prices from 1975 to 1990 for this group of European countries. This would be consistent with economic intuition to the extent that transport technologies have been improving over time for these countries.

assumption that the most productive country in an industry is the sole exporter for products of that industry, providing support for productivity's role as predictor of the direction of trade.

The estimates for the impact of the local cost component of trade costs reported in Table 2 are positive and precisely estimated for each year in our sample, with price elasticities ranging from a low of about 10 percent in 1985 to a high of about 14 percent in 1990 using wage rates, and ranging from about 16 percent in 1985 to a high of 31 percent in 1980 using GDP per capita as a measure of the local cost component of trade costs.

The size of the population is estimated to have a negative statistically significant impact on prices, except for 1980. The estimated negative price elasticity is as high as four percent for 1985. VAT differences have a strong but declining positive impact on price differences ranging from as high as 116 or 126 percent in 1980, based on random or fixed effects estimates reported in columns (5) and (6) of Table 2 respectively, to as low as 67 percent in 1990 reported in column (12), as tax rates become more homogeneous over the period. That is, while VAT rate differences have been very strong determinants of intra-European price differences, they fell in importance by the end of the sample period as would be expected from the EU policy of tax harmonization.

5. Conclusion

Trade costs are important in a number of international macroeconomic models with implications for price deviations across countries. Transport costs are a component of trade costs that has received particular attention in the literature. While technological progress in the transport sector can be expected to reduce their absolute size over time, the relative importance of transport costs can be increasing as policy-related costs of trade decline over time. Moreover, progress in transport technologies might allow previously non-traded goods with higher per unit transport costs to enter international trade. Thus, the relative importance of transport costs in determining price wedges and international quantity flows might remain even as these are declining for any one good.

To enable us to estimate the costs of trading a good internationally, we rank countries based on their productivity in individual industries and compute product-specific international price differences relative to the most productive location for each industry. We have also used information on realized trade flows to determine the probable source of each product as a weighted average of countries from which a destination country actually imports from. Identifying the source has made it possible to consider price comparisons relevant to the direction of trade and trade costs.

In our application, physical distance relative to the origin has a precisely estimated positive impact on international deviations from LOP that is larger than estimates obtained when arbitrarily assigning an equal probability of being the source to each country. Based on our benchmark specifications, the estimated price elasticity of distance for 1990 was estimated to be as high as ten percent using productivity information or about seven percent utilizing trade flows information. Instead, when neither productivity or realized trade flows information is utilized, distance was estimated to have no effect on international price differences whatsoever. Our estimates assign a much bigger importance to distance and trade costs than what is implied by the estimated price elasticities with respect to distance in the literature on international price dispersion.

To conclude, the data are consistent with a model where transport costs and local trade costs are important determinants of international price differences. Our results suggest that utilizing relative productivity and bilateral trade flows along with relative prices from survey data, can help identify trade costs and their role in segmenting product markets. Future work should aspire to utilize microeconomic information on trade flows along with microeconomic relative prices in order to further improve our understanding of trade costs and the relative importance of determinants of international price differences.

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Table 1: Price differentials relative to Most Productive Country for each industry

	1985				1990			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
POP	-0.056***	-0.047***	-0.032***	-0.035***	-0.046***	-0.039***	-0.039***	-0.037***
	(-12.08)	(-7.35)	(-6.76)	(-4.94)	(-7.28)	(-5.29)	(-6.58)	(-5.03)
GDP	0.362***	0.366***			0.256***	0.391***		
	(12.42)	(8.55)			(10.61)	(12.88)		
Wages			0.113***	0.068**			0.170***	0.189***
			(4.82)	(2.45)			(11.31)	(11.71)
Distance	0.082***	0.080***	0.103***	0.084***	0.059***	0.108***	0.078***	0.098***
	(6.59)	(5.89)	(7.62)	(5.22)	(5.65)	(8.96)	(7.09)	(8.26)
VAT	0.446***	0.718***	0.643***	0.889***	0.967***	0.534***	0.871***	0.550***
	(3.28)	(3.72)	(4.40)	(4.23)	(8.43)	(3.70)	(7.56)	(3.79)
R^2	0.094	0.090	0.054	0.048	0.063	0.022	0.099	0.084
Effects	re	fe	re	fe	re	fe	re	fe
Hausman	4.71 [0.32]		7.24 [0.12]		60.88 [0.00]		26.82 [0.00]	
Obss	3189	3189	3115	3115	3755	3755	3755	3755
Countries	7	7	7	7	9	9	9	9

Notes: *** p<0.01, ** p<0.05, * p<0.10. In the "Hausman" row, we report the value of the Chi-squared test and the p-value for the null hypothesis that there is no difference between the random and fixed-effects coefficients. The 9 EU countries considered here are: Austria, Denmark, Germany, Greece, Ireland, Italy, Portugal, the Netherlands, and the UK. For 1985, Greece and Portugal are missing due to the unavailability of the VAT rates in this case. For 1990, we use city-specific population size.

Table 2: Regressions using comparisons relative to trade-weighted probabilistic exporter

	1975		1980				1985				1990			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
POP	-0.018***	-0.019***	-0.008	-0.007	0.016***	0.019***	-0.041***	-0.044***	-0.047***	-0.048***	-0.029***	-0.037***	-0.024***	-0.023***
	(-3.89)	(-3.87)	(-1.47)	(-1.24)	(3.27)	(3.51)	(-9.76)	(-9.73)	(-10.18)	(-9.60)	(-5.85)	(-6.88)	(-5.17)	(-4.67)
GDP	0.287***	0.294***	0.309***	0.311***			0.162***	0.161***			0.204***	0.283***		
	(10.04)	(9.91)	(8.02)	(7.89)			(5.28)	(5.35)			(8.71)	(11.27)		
Wages					0.130***	0.134***			0.104***	0.113***			0.110***	0.139***
					(7.59)	(6.59)			(5.66)	(5.17)			(9.13)	(10.57)
Distance	0.065***	0.077***	0.041***	0.028*	0.042**	0.041*	0.061***	0.077***	0.056***	0.084***	0.018**	0.050***	0.030**	0.069***
	(5.63)	(5.69)	(3.09)	(1.75)	(2.35)	(1.83)	(6.11)	(6.15)	(2.77)	(2.82)	(2.09)	(4.77)	(2.38)	(4.57)
VAT	1.071***	1.107***	0.910***	0.993***	1.155***	1.262***	0.762***	0.747***	0.800***	0.756***	0.919***	0.666***	0.966***	0.816***
	(10.26)	(9.48)	(7.09)	(7.07)	(10.30)	(9.65)	(7.26)	(6.77)	(7.43)	(6.23)	(10.08)	(7.07)	(11.23)	(8.78)
R^2	0.091	0.090	0.049	0.048	0.089	0.089	0.068	0.068	0.109	0.108	0.050	0.048	0.059	0.057
Effects	re	fe	re	fe	re	fe	re	fe	re	fe	re	fe	re	fe
Hausman	3.18 [0.53]		2.36 [0.67]		5.15 [0.27]		6.54 [0.16]		2.41 [0.66]		84.89 [0.00]		42.27 [0.00]	
Obss	2759	2759	2770	2770	2901	2901	5836	5836	4014	4014	6802	6802	5863	5863
Countries	8	8	8	8	7	7	9	9	7	7	12	12	11	11

Notes: *** p<0.01, ** p<0.05, * p<0.10. In the "Hausman" row, we report the value of the Chi-squared test and the p-value for the null hypothesis that there is no difference between the random and fixed-effects coefficients.The 8 countries in the 1975 and 1980 samples are: Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, and the UK. Austria is added in 1985. Greece, Portugal and Spain are added in 1990. The wage rate is missing for Belgium for all years, and for the Netherlands in 1985. For 1990, we use city-specific population size.

Table A1: Industry availability of the TFP level data

Industry Description:	ISIC
Food products	311
Beverages	313
Tobacco	314
Textiles	321
Wearing apparel except footwear	322
Leather products	323
Footwear except rubber or plastic	324
Furniture except metal	332
Paper and products	341
Printing and publishing	342
Other chemicals	352
Miscellaneous petroleum and coal products	354
Rubber products	355
Glass and Products	362
Other nonmetallic mineral products	369
Iron and steel	371
Non-ferrous metals	372
Fabricated metal products	381
Machinery except electrical	382
Machinery electric	383
Transport equipment	384
Professional and scientific equipment	385
Other manufactured products	390

Table A2: Availability of the import flows data

Industry Description:	ISIC
Meat and meat preparations	3111
Dairy products and bird's eggs	3112
Vegetables and fruits	3113
Fish, crustaceans, mollucs, preparations thereof	3114
Margarine, imitat. lard & other prepared edible fats	3115
Fixed vegetable oils and fats	3115
Cereal and cereal preparations	3116
Macaroni, spaghetti and similar products	3117
Bakery products	3117
Sugar and honey	3118
Sugar confectionery and other sugar preparations	3119
Cocoa	3119
Chocolate & other food preptions containing cocoa	3119
Coffee and coffee substitutes	3121
Tea	3121
Spices	3121
Edible products and preparations n.e.s	3121
Alcoholic beverages	3133
Non alcoholic beverages n.e.s	3134
Tobacco and tobacco manufactures	3140
Textile fibres (except wool tops) and their wastes	3210
Textile yarn, fabrics, made up articles, related products	3210
Articles of apparel and clothing accessories	3220
Leather, leather manufactures, n.e.s	3230
Footwear	3240
Furniture and parts thereof	3320
Pulp and waste paper	3410
Paper, paperboard, articles of paper, paper, pulp/board	3410
Registers, exercise books, notebooks, etc	3420
Printed matter	3420
Artificial resins, plastic materials, cellulose esters and ethers	3513
Dyeing, tanning and colouring materials	3521
Essential oils & perfume materials; toilet polishing and cleaning preparations	3523
Chemical materials and products n.e.s	3529
Coal coke and briquettes	3540
Petroleum, petroleum products and realted materials	3540
Rubber manufactures, n.e.s	3550
Other artificial plastic materials, n.e.s	3560
Combs,hair slides and the like	3560

cont.

Glassware	3620
Clay construct. materials & refractory construct. materials	3691
Portland cement, cement fondu, slag cement etc.	3692
Nails,screws, nuts, bolts, etc. iron and steel	3710
Aluminium foil, of a thickness not exceeding 0.20 mm.	3720
Other tools for use in hand	3811
Cutlery	3811
Office machines and automatic data processing equipment	3825
Sewing machines, furniture for sewing mach. & parts	3829
Household type refrigerators & freezers	3829
Telecommunications & sound recording apparatus	3832
Gramophone records, recorded tapes etc..	3832
Household type, elect. & non electrical equipment	3833
Elect. apparel such as switches, relays, fuses, plugs etc.	3839
Batteries and accumulators and parts	3839
Filament lamps, no infra red ultra violet lamps	3839
Int combustion piston engines for outboard prop.	3841
Passenger motorcars,for transport of pass.&goods	3843
Motorcvcles, motorscooters, invalid carriages	3844
Photographic apparatus, optical goods, watches	3850
Medical instruments and appliances	3850
Orthopedic appliances, surgical belts	3850
Pins & needles, fittings, base metal beeds etc.	3900
Children's toys, indoor games	3900
Other sporting goods and fairground amusements	3900
Pens, pencils and fountain pens	3900
Jewelry, goldsmiths and other art. of precious metals	3900
Musical instruments, parts and accessories	3900
Meahanical lighters and parts	3900