Price dispersion: the role of borders, distance, and location

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Abstract

We present a competitive equilibrium retail-pricing model that suggests a role for trade costs and non-traded input costs as determinants of the mean and variance of deviations from the law of one price. Using absolute price data on 304 goods and services from 122 locations across and within 79 countries for the period 1990 to 2000, we find that this benchmark model goes a long way towards explaining both the cross-country variation in the real exchange rate, and the cross-country variation in the variance of deviations from the law of one price across goods.

Keywords: Law of one price, PPP, transportation costs, geography.
JEL Classification: F3

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1 Introduction

A stylized fact of international macroeconomics is that international price differences are typically bigger than intranational price differences. To the extent that the latter phenomenon cannot be explained solely by the geographic distance between locations, it has been attributed to the "border effect." The latter is often attributed to the fact that, unlike intranational prices, international prices are subject to exchange rate variation.

Nominal exchange rate variation in the presence of sticky prices has been proposed by Engel (1993), Engel and Rogers (1996), and Parsley and Wei (2001) as a major determinant of real exchange rate variation and border size. In fact, a number of factors can be important in shaping this so called "border effect." For example, the size of the border will depend on international differences in non-traded input costs. A "border effect" will be present when the non-traded inputs like labor and land that go into the production of retail goods face identical or similar costs (wages and rent) across locations within countries but very dissimilar costs across countries. Crucini, Telmer, and Zachariadis (2001) document substantial Law of One Price (LOP) deviations and an important role for non-traded inputs in explaining these international price differences across European countries for the period 1975 to 1990, consistent with a model of retail price determination. They also document that Purchasing Power Parity (PPP) was a good approximation for European countries in that period even though there were large swings in nominal exchange rates throughout that period.

The size of the border for any one good could also vary with individual characteristics like tradeability and the value of the good, in the presence of iceberg transportation costs. The importance of trade costs in determining price differences is suggested, among others, by the work of Betts and Kehoe (2001), Stockman and Tesar (1995), and Crucini, Telmer, and Zachariadis (2001.) Berka (2002) presents a model where the value of a good determines the "no-trade bounds" for that good. Rossi-Hansberg (2002) considers a spatial model where transport costs and trade barriers have important and distinct economic implications across regions and countries. Hummels (1999a) suggests transportation costs are important since import choices are made in order to minimize such costs so that they constitute only a small fraction of overall expenditure. Finally, Hummels (1999b) shows that transportation costs have often not fallen over the last few decades, suggesting that such costs can still play an important role in trade and price determination.
across international markets.

Here, we take the opposite view that Engel and Rogers do, namely that sticky prices explain much of the behavior of real exchange rates. Our starting point is that trade costs and non-traded inputs into retail price determination account for virtually all dimensions of absolute price deviations (variance in means, variance in variances, role of distance and income). Moreover, once these deviations are understood it is natural that nominal exchange rate fluctuations play a role; namely in moving relative prices within the band of arbitrage. We present a competitive equilibrium retail model that suggests a role for trade costs and non-traded input costs as determinants of the first and second moments of the distribution of deviations from the law of one price. In contrast, models based on country-wide nominal exchange rate shocks have implications about the mean real exchange rate (the first moment of the deviations from LOP distribution) but do not offer reasonable implications regarding the variance of LOP deviations across goods for bilateral country comparisons.

Using absolute price data on 304 goods and services from 122 locations across and within 79 countries for the period 1990 to 2000, and using distance and GDP per capita levels to capture transportation costs and non-traded input costs respectively, we find that this benchmark model goes a long way towards explaining both the cross-country variation in the real exchange rate, and the cross-country variation in the variance of deviations from the law of one price across goods.

2 Retail price determination

We find it useful to describe the dimensions relating to distance and those relating to income levels in the model outlined below. For example, we would think of distance as manifesting itself in the imported intermediate goods, while income primarily impacts the non-traded input prices.

The fact that prices are not equalized across countries is not unexpected and many theories have been-developed to account for deviations from the Law-of-One-Price and Purchasing Power Parity. Moreover, most theories are sufficiently general that they may be applied to both intranational and international price determination. Often the distinction between the two is quantitative rather than qualitative. Perhaps the most general theory is due to Debreu (1959) who includes location as one of the dimensions along which a commodity-space is defined.
When thinking about the locational aspect of trade and price determination, most economists have in mind either the transportation cost of moving the goods from the location of the seller to the location of the buyer or official barriers to trade (e.g. tariffs, quotas and other trade regulations). In an age in which transportation costs are quite modest relative to the price of goods and tariff barriers have been reduced if not eliminated, these types of barriers are unlikely to explain a substantial fraction of international (or intranational) price dispersion. We believe a minimum of two additional factors must be incorporated: i) the costs implicit in the movement of goods from the factory to the retail floor and (ii) departures from perfect competition.

We have found that using the dual problem of cost minimization is a useful and tractable conceptual framework for embedding these various theoretical ideas and pursuing quantitative exercises (accounting and estimation). We model retail firms as specialists in selling a particular good in a particular location. Each of these firms is a price taker in factor markets (i.e. takes input prices, including traded inputs as given), but may have market power in the local retail market. Here, inputs include both non-traded and traded goods and/or services. Non-traded inputs are locally provided while traded inputs are either exported or imported.

Formally, the cost function for the individual retail firm is the solution to the following minimization problem solved at each date:

\[
\min \{ L_{jt}, X_{jt} \} \quad C_{jt}^i = W_{jt} L_{jt} + \sum_{s=1}^{S(i)} \tilde{P}_s X_{jt}^s
\]

\[
\text{s.t.} \quad f^i(L_{jt}, X_{jt}^i) \geq Y_{jt}^i \equiv (L_{jt})^{\alpha_s} (\prod_{s=1}^{S(i)} (X_{jt}^s)^{\theta_s})^{(1-\alpha_s)}
\]

where \(C_{jt}^i\) is the cost of producing good \(i (= 1, \ldots, N)\) in location \(j (= 1, \ldots, M)\) at time \(t (= 1, \ldots, T)\), \(L_{jt}^i\) is the labor input, \(X_{jt}^i = \left( X_{jt}^1, X_{jt}^2, \ldots, X_{jt}^{S(i)} \right)\) is a vector of traded intermediate inputs, \(W_{jt}\) is a wage common to all sectors that differs across locations, \(\tilde{P}_s\) is the price of traded intermediate input \(s\) in location \(j\), \(0 < \alpha_s < 1\) and \(\sum_{s=1}^{S(i)} \theta_s = 1\). It is natural to think of retailers paying for non-traded inputs beyond labor services (e.g., retail space, utilities, advertising, among others), but the wage cost will suffice for expositional purposes.

We consider trade in goods and services as an equilibrium outcome, rather than a characteristic of a good or service. We use the term to distinguish between factor inputs that are purchased in the location of retail sale from inputs which are exported from, or imported to the location of sale. In this way, the prices of the
traded intermediate goods are assumed to deviate from the Law-of-One-Price by exactly the wedge created by traditional costs of trade across locations (transportation costs and official barriers to trade), while the factor inputs which are locally produced (here, labor services) are by definition not traded. This is not the same thing as saying that trade across locations has no impact on wage or rental rates across locations. Labor mobility place bounds on wage differentials across locations. Financial market integration and trade in capital goods (e.g. machines) serves a similar function in terms of rental rates. Similar arguments place bounds on the deviations from the Law-of-One-Price on the retail goods themselves (why purchase a computer at an electronic store when it may be available at lower cost on the internet?).

Turning to the details, as is implicit in the indexing we have adopted two standard assumptions. The first is that factor mobility is much higher across sectors within a location than across locations — W is location-specific, not good-specific. The second assumption is that retailers in all locations produce good j using the same production technology — α and θ are good-specific, not location-specific.

Under constant returns to scale, the cost function will take the form: $Y_{jt} \cdot C_i(P_{jt}, 1)$ where $Y_{jt}$ is the desired real output level, $P_{jt} = \{W_{jt}, \bar{P}_{jt}, \bar{P}_j, \ldots, \bar{P}_s^{(i)}(i)\}$ and $C_i(P_{jt}, 1)$ is the unit cost function, the object of interest. We allow the retailer to set a location-specific — possibly time-varying — markup over marginal cost, $b_{jt} \geq 1$, so the per unit retail price of good i faced by a consumer in location j, $P_{jt}^i$, is:

$$P_{jt}^i = b_{jkt}^i(W_{jt})^\alpha_i \left(\bar{P}_{jt}^i\right)^{1-\alpha_i}$$  \hspace{1cm} (3)

where $b_{jkt}^i = \ln\left(b_{jt}^i/b_{kt}^i\right)$, $w_{jkt} = \ln\left(W_{jt}/W_{kt}\right)$, and $\tau^i_{jkt} = \ln\left(P_{jt}/\bar{P}_{kt}\right)$.

Taking logarithms of (3) and subtracting an analogous expression for k is our measure of the Law-of-One-Price deviation of good i for bilateral pair jk:

$$q_{jkt}^i = \ln(e_{jkt}P_{jt}^i/P_{kt}^i) = b_{jkt}^i + \alpha_i w_{jkt} + (1 - \alpha_i) \tau^i_{jkt}$$  \hspace{1cm} (4)

where $b_{jkt}^i = \ln\left(b_{jt}^i/b_{kt}^i\right)$, $w_{jkt} = \ln\left(W_{jt}/W_{kt}\right)$, and $\tau^i_{jkt} = \ln\left(P_{jt}^i/\bar{P}_{kt}^i\right)$.

To examine the variance in the means question, we must aggregate the expression across goods, to arrive at the implications for Purchasing Power Parity:
\begin{equation}
q_{jkt} = \sum_{i=1}^{N} \omega^i q^i_{jkt} = \left( \sum_{i=1}^{N} \omega^i \alpha^i \right) w_{jkt} + \sum_{i=1}^{N} \omega^i (1 - \alpha^i) \bar{\tau}_{jkt}^i + b_{jkt} \tag{5}
\end{equation}

\begin{equation}
= \alpha w_{jkt} + \frac{1}{N} \sum_{i=1}^{N} (1 - \alpha^i) \bar{\tau}_{jkt}^i + b_{jkt}, \text{ with } \omega^i = \frac{1}{N} \text{ and } \alpha \equiv \omega^i \sum_{i=1}^{N} \alpha^i \tag{6}
\end{equation}

Where is the geography of this equation?

- Principle #1: Richer countries tend to have higher wages and other non-traded input costs (rental rates, land prices). This is what we see in Figure Y below and in Table X where the correlation between the real exchange rate and relative income is shown to be 52 percent:

![Figure Y](image)

- Principle #2: At the aggregate level, the cost of traded intermediate goods used in country \( j \) relative to the world average could average out to be of minor significance. For example if we import some goods and export others, these would appear as pluses and minuses in the aggregation. Overall, the
impact of traded intermediate inputs on absolute deviations from PPP is expected to be small. Assume that traded intermediate inputs exchange at relative prices that reflect only trade costs (transportation and possibly the costs due to official barriers to trade). With sufficient symmetry in trading patterns, technology and expenditure weights, the aggregate value of this expression should be close to zero since it is averaging trade costs of opposite sign. The implication of this logic is that aggregate real exchange rates for traded intermediate inputs should be zero (See Table X first row first column.)

• Principle #3: The impact of trade costs on real exchange rates should be more evident in the absolute values of law of one price (LOP) deviations. Had we taken the absolute value of an aggregate real exchange rate we would obviously understate the implications of trade costs since: $|m| + |n| \geq |m+n|$ and since the value inside the absolute value sign on the right-hand-side may be either negative or positive. The difference is important because it highlights the fact that if we look to PPP estimates for evidence of trade costs (or other sources of differences in relative prices) we are likely to systematically underestimate them when the signs alternate across goods and/or locations. This also means that when we account for international price dispersion we will need to examine levels for some purposes and absolute values of levels for others. A comparison of the correlations in the first, second, and third rows of the first column of Table X is informative about this supposition.

<table>
<thead>
<tr>
<th>TABLE X – CORRELATIONS</th>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>real exch. rate</td>
</tr>
<tr>
<td>absolute real exch. rate</td>
</tr>
<tr>
<td>mean of absolute LOP deviations</td>
</tr>
<tr>
<td>variance of LOP deviations</td>
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<tr>
<td>log-Distance</td>
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</tbody>
</table>

• Principle #4: The impact of price discrimination on the real exchange rate depends on the relative markups across locations. Thus, if a monopolist sells in multiple markets and faces the same cost and demand elasticity in each one, the real exchange rate should not be affected even if the absolute markup over cost is substantial in both locations. Empirically, this is the part of the equation that is most difficult to get a handle on since it requires measures of both prices and quantities to capture costs and demand elasticities in each location.
Dispersion in the variance of deviations from LOP

Principles #1-#4 relate to our ‘analysis of means,’ the dispersion in real exchange rates. The next principle relates to the ‘analysis of variance’ around these means. That is, we are also interested in how much variation there is across goods in Law-of-One-Price deviations for a given bilateral comparison. Our interest in price dispersion at the microeconomic level orginates with our earlier work, Crucini, Telmer and Zachariadis (2000, 2001.) In this earlier work, we related good-by-good geographic price dispersion across EU countries to individual characteristics of the goods (non-traded inputs, extent of trade, etc) with considerable success. Here we build on similar themes but using bilateral comparisons and exploring the role of geographic distance and income differences.

Returning to our retail model, the variance in Law-of-One-Price deviations across goods for a given location is:

$$\text{var}(q_{jkt}) = \text{var}(\alpha_i w_{jkt} + (1 - \alpha_i) \tau_{jkt} + b_{jkt})$$

which involves a fairly complicated variance-covariance structure. Consider the first term. It’s the simplest because the variance across goods is isolate to the production parameter $\alpha_i$ while the locational wage differential is just that, location specific (as opposed to good specific). Our first prediction for variance in the variances is:

- **Principle #5:** In the absence of trade costs or markups, the variance of Law-of-One-Price deviations for a pair of locations rises with the share of non-traded inputs into production in proportion to the wage differential across the locations (more generally we would look at the price differential for non-traded inputs). To see this, set the last two terms of the variance expression to zero and we simply have:

$$\text{var}(q_{jkt}) = \text{var}(\alpha_i) w_{jkt}$$

or in words, the dispersion in Law-of-One-Price deviations is the product of the differences in non-traded input shares across goods (assumed to be good and not location specific) and a fixed wage difference between a location and the numeraire. Thus, armed with a distribution of non-traded inputs shares $\alpha_i$ across goods (assumed here to be common across countries – same technology and Cobb-Douglas technology) and a wage differential measure, we would have a complete characterization.
of the variance in variances. Consider a back-of-the-envelope calculation from Crucini, Telmer, and Zachariadis (2001.) There we found that the average share of non-traded inputs for goods that we classified as non-traded was 24.6 with a standard deviation across goods of 7.4; comparable statistics for traded goods are 11.5 and 3.0. If we assume that traded goods have dispersion across goods that is only a function of distance and not income, then the additional standard deviation across goods added by the contamination of retail prices through non-traded inputs is given by \( \text{var}(\alpha^i) \log(w_j/w_k) \) and assuming wages (e.g. non-traded prices) are proxied by income differences, we have: \( \text{var}(\alpha^i) \log(y_j/y_k) \) and the \( \sigma_{jk} \) should display a V-shape with a minimum for locations with equal income. The figure that conveys the message quite clearly is a plot of the variance of Law-of-One-Price deviations against the logarithm of relative income (log relative income being a good proxy for log relative wages \( w_{jt} \)). Such a figure should have a distinct V-shape with the point of the ‘V’ being two locations with identical income levels. Figure V shows this pattern very distinctly. As we move from regions with similar income levels to regions with different income levels, the variance in variance rises.

![Relative Income versus Loc-Specific Price Dispersion](image)

Figure V
3 Data

The source of our price data on individual goods and services is the Economist Intelligence Unit which collects retail prices of 220 goods and 84 services across outlets within major cities across the globe. The total number of locations (cities) is 122, spanning 79 countries. In practice we use between 243 and 287 goods (reasons are explained in the data appendix). We use intranational locations in France (2 cities), Germany (5 cities), Italy (2 cities), Russia (2 cities), Spain (2 cities), Switzerland (2 cities), UK (2 cities), China (5 cities), India (2 cities), Japan (2 cities), Saudi Arabia (3 cities), Vietnam (2 cities), Australia (5 cities), New Zealand (2 cities), Canada (4 cities) and U.S. (16 cities.) The sample period is annual, beginning in 1990 and ending in 2000. These data are also used in Crucini and Shintani (2002) and Parsley and Wei (2002.) and a subset (Europe) has been used in Rogers (2001) and Rogers (2002.)

The rudimentary element of our analysis is the logarithm of the ratio of the U.S. dollar price of an individual good in location \( j \) relative to location \( k \):

\[
q_{j\bar{=}k} = \log \left( \frac{p_{j\bar{=}k}^j}{p_{j\bar{=}k}^k} \right)
\]

The international macroeconomics literature has focused on PPP, which we approximate by the equally-weighted mean,

\[
q_{j\bar{=}k} = \frac{1}{N} \sum_{i=1}^{N} q_{j\bar{=}k}^i
\]

In earlier work we found that equal-weighting resulted in real exchange rates that were comparable to consumption-expenditure weighted versions. We choose to maintain the equal weighting to preserve the statistical properties of the mean and standard deviation. That is, in thinking of Law-of-One-Price deviations we wish to understand the mean of these deviations across goods for a given bilateral pair as well as the standard deviation of the deviations across goods. Thus equal-weighting seems the natural choice. In what follows, we refer to \( q_{j\bar{=}k} \) as the real exchange rate and reserve the term Law-of-One-Price deviation to describe \( q_{j\bar{=}k}^i \).

4 Variation in the Mean or the Variance?

There are many plausible explanations for the observed patterns of Law-of-One-Price deviations underlying our data. For example, it could be that all goods prices differ by a fixed proportion across a given bilateral pairing. If this were literally true, all of the variation in \( q_{j\bar{=}k}^i \) would be accounted for by variation in the mean \( (q_{j\bar{=}k}) \) and none would be specific to the good. In such a world, Law-of-One-Price deviations are the same thing as PPP deviations (i.e. everything is either cheaper or more expensive in location \( j \) relative to \( k \) by
a given percentage). We use the statistic $\text{Var}_{jk}(q_{jk})$ to refer to the variance of real exchange rates across all bilateral pairs. The PPP proposition is about the level of $q_{jk}$ — is it zero or not? Theoretical models that allow for deviations from PPP are built to explain (or literally account for) the variance of the PPP deviations across countries. If all of the deviations from price parity are location specific (as opposed to partly good-specific), this is all we need to know.

At the opposite extreme, we could have Law-of-One-Price deviations across two locations that exactly averaged out across goods so that $q_{jk} = \sum_{i=1}^{N} q_{ijk} = 0$ despite the fact that each $q_{ijk}$ is large. A simple explanation for this is the iceberg cost model. Consider two goods, one which is imported and one which is exported, both with trade costs of the same proportional amount $\tau$ (trivially we get $\tau - \tau = 0$). So long as $\tau$ does not depend too much on the good and the bilateral trading relationship is extensive, we expect $q_{jk} = \frac{1}{N} \sum_{i=1}^{N} [D_{jk}^{i} \tau_{jk}^{i} - (1 - D_{jk}^{i}) \tau_{jk}^{i}] = 0$. Where $D_{jk}^{i}$ is a dummy variable taking on the value of 1 if trade flows from region $j$ to $k$ in good $i$. In this case, the distribution of $q_{jk}$ is degenerate at zero and the variation in Figure 1 incorporates good specificity, reflecting the international patterns of good-specific transportation cost and trade flows. In this case, we’d like to look at the variation in Law-of-One-Price deviations across goods, for each bilateral pair, namely $\sigma_{jk} = \sqrt{\text{Var}(q_{jk}^i | j, k)}$.

### 4.1 Variance in the Mean

We begin with the first moment of the distribution, averaging across goods, $q_{jkt} = \alpha w_{jkt} + \frac{1}{N} \sum_{i=1}^{N} (1 - \alpha^{i}) \tau_{jkt}^{i}$, where $\alpha \equiv \frac{1}{N} \sum_{i=1}^{N} \alpha^{i}$ and we have ignored $b_{jkt}$ on the grounds of how hard it is to measure this. The first term is the Balassa-Samuelson part of the story: the average Law-of-One-Price deviation is proportional to the wage differential. For example, if county $j$ is Portugal, a country with wages well below the European average, the price level will also be well below average. In fact, according to our model, determining how much lower is a matter of taking the product of two numbers: the relative wage and the average production parameter $\alpha$. The second term involves the convolution of two good-specific factors (the production share and the trade cost). The implications of trade costs will be more transparent if we focus on a bilateral pair since it allows us to make the direction of trade explicit. The implications of trade costs for the mean Law-of-One-Price deviation across locations $j$ and $k$ is:

$$\frac{1}{N} \sum_{i=1}^{N} (1 - \alpha^{i})(\tau_{jkt}^{i} - \tau_{jkt}^{i}(1 - D_{jk}^{i}))$$

(8)
where $D_{jk}^i = 1$ if good $i$ is imported into $j$ from $k$ or zero if it is exported from $i$ to $k$. The equation, therefore, consists of the sum of transportation costs with alternating signs across imported and exported items. We expect this sum to be quantitatively small. For example, if there were two countries each specialized in the production of a single good with a common $\alpha$, the trade cost would average exactly to zero and the Law-of-One-Price holds ‘on average.’ In the absence of symmetry in non-traded input shares and trade costs across goods and countries, the aggregation result will not hold. However, we expect the economic magnitude of any impact on the (mean) real exchange rate to be quite small.

To get a sense of the potential quantitative importance of these distinctions, we present some figures before turning to our descriptive statistics and more structured statistical analysis. Figure 1 presents the distribution of the means (the real exchange rates), $q_{jk}$, for both intranational and international comparisons. Obviously there is variation, though much less than what one finds for law of one price deviations. This suggests that Law-of-One-Price deviations have both location and good-specific characteristics. Note, however, that the intranational real exchange rate distribution is less dispersed than the international real exchange rate distribution. In other words, deviations from PPP are greater across countries than across cities within countries.

Figure 1: Density function of real exchange rates.
The next question that naturally arises is: Does the type of good we examine matter for the magnitude of the Law-of-One-Price (either internationally or intranationally)? The answer is yes. Non-traded goods have greater geographic price dispersion both within and across countries, but particularly across countries. Aggregating across goods within each category (i.e. traded and non-traded), we produce PPP estimates for traded and non-traded goods. This gets at a common issue raised when examining micro-data. We know that within city price deviations exist for both traded and non-traded goods, so we would like to average out some of that variation and compare price levels in each category. If traded goods sold on average for the same price across locations we would expect the density for traded goods to be degenerate at zero. In Table 1 we do see a greater tendency for price deviations to average out for traded goods than for non-traded goods, as we would expect. The effects are also more pronounced for the intranational case than for the international case. Table 1 reports the variance of real exchange rates across locations within and across countries ($\text{Var}_{jk}(q_{jk})$). Beginning with the sample that includes all goods, we see a sharp decline in dispersion as we move from the international data to the intranational data, with the standard deviation dropping from 0.35 to 0.12. The ‘border’ by this metric adds about 23 percentage points to the standard deviation of mean real exchange rates.

We note here that nominal exchange rate variation also contributes to real exchange rate dispersion. This is most evident if we attribute the differences between international and intranational variability in real exchange rates to the nominal exchange rate variation alone (i.e. a common currency area versus a bilateral pairing with different currencies). Given that many other theories (e.g. Balassa-Samuleson) apply to this comparison, it is useful to look at the international data alone for evidence of this (Parsley and Wei, do a much more thorough job on this particular question). Dividing countries into high and low nominal exchange rate categories we do, in fact, find evidence of the impact of time variation in nominal exchange rates on point-in-time real exchange rate dispersion. Taking the numbers at face value, less stability in the nominal exchange rate (e.g. represented by our thresholds as a move from a standard deviation of 4% to 54%), adds about 11% to the border. The results for intranational real exchange rates suggest that nominal exchange rate fluctuations are felt equally across locations, so the nominal exchange rate variation has purely nation-specific effects. That is, nominal exchange rate fluctuations in a given country appear not to affect price dispersion across regions within that country.
Apart from fluctuations in nominal exchange rates, income levels and distance are thought to be key determinants of deviations from PPP. We examine the role of these factors by conditioning on income differences and the distance (as measured by the greater circle distance) across bilateral locations. Table 1 reports the variance of real exchange rates after controlling for these factors. As we do not currently possess income levels by city within countries, for the intranational comparisons we condition only on distance. Below we present densities of real exchange rates comparable to Figure 1 after controlling for income (in Figure 2) and both income and distance in Figure 3. We also present the related statistics in Table 1.

**TABLE 1 – DISPERSION IN REAL EXCHANGE RATES**

<table>
<thead>
<tr>
<th>Sample selected</th>
<th>International</th>
<th>Intranational</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw data</td>
<td>Controlling for:</td>
</tr>
<tr>
<td></td>
<td>income</td>
<td>income and distance</td>
</tr>
<tr>
<td>All goods, All cities</td>
<td>0.354</td>
<td>0.303</td>
</tr>
<tr>
<td>Non-Traded, All cities</td>
<td>0.444</td>
<td>0.366</td>
</tr>
<tr>
<td>Traded,Low-price, All cities</td>
<td>0.362</td>
<td>0.328</td>
</tr>
<tr>
<td>Traded,High-price, All cities</td>
<td>0.325</td>
<td>0.290</td>
</tr>
</tbody>
</table>

Notes: By high (low) exchange rate variation we mean the standard deviation of the nominal exchange rate is more (less) than 10% per year.

Using all goods and locations we find that income differences account for about five percentage points of the observed variability in international real exchange rates. The effect is quite muted for traded goods, but much stronger for non-traded goods where the standard deviation falls by eight percentage points from 0.444 to 0.366. The Balassa-Samuelson model would predict an income effect on non-traded goods, but not traded goods. However, at the retail level all goods require some non-traded inputs which probably contaminates the data relative to what that theory predicts. The share of non-traded inputs in the non-traded goods is about 24% while the share for traded goods is about 11%\(^1\). The fact that conditioning on income reduces real exchange rate variability by twice as much for non-traded goods compared to traded goods (eight percentage points versus 3.5 percentage points) may reflect the halving of the non-traded input share as we move from non-traded to traded goods.

\(^1\)These numbers are obtained using input-output data matched to the Eurostat data by ISIC category from Crucini, Telmer, and Zachariadis (2001) rather than the EIU data. We note here though that the composition of the Eurostat and EIU data is similar in terms of breadth.
Table 1 also shows that distance matters even after controlling for income differences. In fact, using all goods in the comparisons the standard deviation falls from 0.30 to 0.18 when we control for the distance between locations. This is evident in Figure 3. More puzzling is the fact that distance does not seem to much affect the dispersion of prices within countries, with the standard deviation going only slightly down, from 12.3 percent from 11.4 percent once we control for intranational distance. It could be that within country regions are so economically integrated that real exchange rate differences across cities are just very low to begin with. Similar technology and productivity levels across locations within a country might be responsible for similar prices even across distant locations within a country and in the absence of trade. Another possibility is that the patterns of income (which are unobserved in the intranational analysis) are obscuring the impact of trade.
4.2 Variation in the Variances

The question that remains is how disperse individual price deviations are around the bilateral means. We could certainly have a situation in which, after controlling for the average price differences across two locations, the dispersion of prices across goods is greater across locations within countries than across cities of the world. Similarly we could have more dispersion in prices within cities than across them. To understand the variation across goods for bilateral comparisons we need to examine the variation in the variance

\[ \sigma_{jk} = \sqrt{\text{Var}(q_{jk} | j, k)}. \]

Table 2 shows that the cross-sectional variance of deviations from LOP depends on the same factors as the dispersion in real exchange rates. This dispersion rises from 0.54 to 0.696 when we go from traded goods to non-traded ones. Among traded goods, dispersion rises from 0.54 for high-price goods to 0.63 for low-price goods.
TABLE 2 — DISPERSION ACROSS GOODS

<table>
<thead>
<tr>
<th>Sample selected:</th>
<th>International</th>
<th>Intranational</th>
</tr>
</thead>
<tbody>
<tr>
<td>All goods and cities</td>
<td>0.645</td>
<td>0.392</td>
</tr>
<tr>
<td>Non-Traded, all cities</td>
<td>0.696</td>
<td>0.474</td>
</tr>
<tr>
<td>Traded, low-price, all cities</td>
<td>0.63</td>
<td>0.37</td>
</tr>
<tr>
<td>Traded, high-price, all cities</td>
<td>0.54</td>
<td>0.31</td>
</tr>
</tbody>
</table>

The patterns of intranational and international price dispersion deliver a number of clear messages. First, there is less dispersion of prices within countries than across them. Moreover this is true for both traded and non-traded goods. Second, the price differences that exist at the micro-level tend to average out across goods within each bilateral comparison. That is, PPP holds to a better approximation than the Law-of-One-Price. The characteristics of the goods used in each of the comparison alters the outcome. Traded goods generally have less dispersion than non-traded goods.

5 Borders

Here, we undertake a more formal investigation of the border. First, we seek to explain the absolute value of the real exchange rate across locations with distance as a proxy of transportation costs, and income per capita as a proxy for non-traded input costs. We estimate

$$|q_{jk}| = \alpha + \beta \log D_{jk} + c_b + \gamma \ln D_{jk} \ast c_b + \delta X_{jk} + \text{residuals}$$ (9)

where D stands for distance between locations j and k, X stands for the absolute log income per capita difference between any two international locations, and $c_b$ is a border dummy taking the value of one for international comparisons. The interaction term in this equation is a novelty of our approach and is suggested by the visual evidence in Figure 4 below. Figure 4 plots $q_{jk}$ against log distance, after taking out wealth effects.² Squares are plotted for comparisons of locations within countries and dots for international comparisons. Figure 4 suggests that distance and the border interact with each other so that the usual distance regressions are characterized by an identification problem. We see that intranationally distance appears to have no effect on dispersion. Internationally it does.³ We address this by including an interaction

²That is, $q_{jk}$ is the residual of a regression of the log real exchange rate on log relative income (the coefficient of income here is 0.1657 with a standard error of 0.0032.) The same phenomenon for international versus intranational distance impact is even more emphatically present when we plot the (unadjusted) log real exchange rate against log distance.

³If we consider a regression of $q_{jk}$ on distance internationally, the coefficient is 0.0068 with a standard error of 0.0026, whereas intranationally the distance coefficient is statistically indistinguishable from zero, estimated at -0.0029 with a standard error of 0.0069. It’s therefore clear that the slope coefficient for distance is differs for international versus intranational comparisons.
term between distance and the border in our border regressions.

Figure 4: Price differences across inter and intranational locations plotted against distance.

Figure 4A (not removing income effects)

What this says is that as we increase distance, dispersion increases but only for international locations. The above suggests that you can’t simply decompose price dispersion into border and distance effects: they interact in an important way. The bottom line in terms of the standard "border regression" is that it’s misspecified. This is why we need a specification which incorporates interaction effects.
In Table 3, we present estimates of the impact of distance, income, and the border on price dispersion. The constant in the first row relates to intranational locations and so does the log-Distance coefficient in the second column. The Border coefficient is the deviation of international locations from the magnitude of the constant reported in the first column. Similarly, the log-Distance×Border coefficients in the fourth column measures the deviation of the distance estimate for international locations from the magnitude of the intranational log-Distance coefficient reported in the second column. In the fifth column, we report estimates for the effect of income (proxying for non-traded input costs like labor and rental costs) on price dispersion across countries.

In the first two rows of Table 3, we consider the absolute value of the first moment of the distribution of LOP deviations, the absolute mean real exchange rate. First, distance does not enter positively or significantly intranationally.\(^4\) Second, distance enters positively internationally with coefficients of 0.0044 for the regression in row one as we can see by summing the coefficients in columns two and four. The standard error is .0031\(^5\) which renders this estimate (marginally) insignificant. Third, distance does not enter positively or significantly intranationally or internationally once we include income per capita. These results are consistent with our averaging-out hypothesis for transportation costs. We alleviate this problem by considering the mean of absolute law of one price deviations next. Moreover, crossing the border does not have a statistically significant impact on price dispersion as we can see in column three.\(^6\) Finally, international income differences have a strong positive impact on the dispersion of means (real exchange rates) consistent with a model where non-traded inputs play an important role in the determination of relative prices.

\(^4\)Thus, one cannot translate the border effect into physical distance in the usual way.

\(^5\)We consider a regression for international locations alone. This provides a coefficient equal to the sum of the coefficients reported in columns two and four, along with its standard error.

\(^6\)We also consider the residual from the regression of the absolute mean real exchange rate on income and relate this to distance and the border. In that case, the estimates for the constant, intranational distance, the border, and the interaction term are 0.1576(0.1020), -0.0029(0.0140), 0.0256(0.1045), and 0.0096(0.0142) respectively, with the standard errors in parentheses. Again, crossing the border does not seem to matter, the international distance coefficient which equals 0.0067(=−0.0029+0.0096) with a standard error of 0.0026 positive and statistically significant unlike the intranational distance coefficient.
### TABLE 3 - "BORDER" REGRESSIONS

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Constant</th>
<th>log-Distance</th>
<th>Border</th>
<th>log-Distance × Border</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>absolute real exch. rate</td>
<td>0.1303</td>
<td>-0.0044</td>
<td>0.1140</td>
<td>0.0088</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1227)</td>
<td>(0.0168)</td>
<td>(0.1257)</td>
<td>(0.0171)</td>
<td></td>
</tr>
<tr>
<td>means of absolute LOP deviations</td>
<td>0.2288</td>
<td>0.0106</td>
<td>0.1630</td>
<td>0.0111</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0791)</td>
<td>(0.0109)</td>
<td>(0.0810)</td>
<td>(0.0110)</td>
<td></td>
</tr>
<tr>
<td>variance of LOP deviations</td>
<td>0.3131</td>
<td>0.0110</td>
<td>0.1262</td>
<td>0.0044</td>
<td>0.0649</td>
</tr>
<tr>
<td></td>
<td>(0.0488)</td>
<td>(0.0066)</td>
<td>(0.0494)</td>
<td>(0.0067)</td>
<td>(0.0012)</td>
</tr>
</tbody>
</table>

Note: The income variable in the last column refers to absolute log relative income levels. Standard errors are reported in parentheses below each coefficient estimate.

In Table 3, we also consider the means of absolute LOP deviations rather than the absolute value of the real exchange rate (the mean of LOP deviations.) The prediction from Principle #3 is that this measure will have a stronger relation with distance than the real exchange rate or its absolute value. Indeed, the coefficient of distance for international bilateral comparisons obtained by summing the coefficients in columns two and four, is 0.0217 for the regression in the third row and 0.0113 for the regression with income differences in the fourth row, both larger than the estimates obtained using the absolute real exchange rates reported in the first and second rows. The international distance coefficient estimates are statistically significant beyond the one percent level, with the standard error for both estimates equal to 0.002. As we can see in the second column of Table 3, distance does not appear to matter as much within countries. The international distance coefficient of 0.0217 from the regression in the third row of Table 3 compares to an intranational coefficient half its size at 0.0106.

#### Dispersion in the variance of deviations from LOP

We also consider dispersion in the cross-sectional (across goods) variance of deviations from LOP by estimating the following specification:

\[ \sigma_{jk} = \alpha + \beta \log D_{jk} + c_b + \gamma \ln D_{jk} \times c_b + \delta X_{jk} + \text{residuals} \]

We report the results from the above estimation in the last two rows of Table 3. Now, distance enters positively for intranational and international locations. For the regression in the fifth row of Table 3, the coefficient of distance is much larger internationally at 0.025 compared to 0.011 intranationally. The standard error for the international distance estimate is 0.0014, rendering this estimate statistically significant beyond
the one percent level. This is consistent with the role of transportation costs in the determination of retail prices through the impact on imported input costs. By contrast, the intranational distance coefficient estimate is insignificant in row five, and marginally significant in row six for the regressions that accounts for income differences. Finally, international income differences have a strong positive impact on the dispersion of variances of LOP deviations, again consistent with our retail-pricing model. Nevertheless, crossing the border appears to have a strong positive and statistically significant impact on the second moment of the distribution of LOP deviations, as we can see in rows five and six of column three.\footnote{However, to the extent that distance does not matter intranationally, the border cannot be measured in terms of physical distance as in the papers by Engle and Rogers (1996) or Parsley and Wei (2001) since that calculation includes intranational distance, here statistically indistinguishable from zero, in the denominator.}

6 Conclusions

We present a competitive equilibrium retail-pricing model that suggests a role for trade costs and non-traded input costs as determinants of the mean and variance of deviations from the law of one price. Using absolute price data on 304 goods and services from 122 locations across and within 79 countries for the period 1990 to 2000, and employing distance and GDP per capita levels to capture trade costs and non-traded input costs respectively, we find that this benchmark model goes a good distance towards explaining both the cross-country variation in the real exchange rate, and the cross-country variation in the variance of deviations from the law of one price across goods. Relative income is an important determinant of both the mean and the variance of deviations from the law of one price, consistent with a model where non-traded input costs are a determinant of retail prices. Moreover, distance matters for international price dispersion but does not matter for intranational price dispersion, suggesting that distance and the border interact with each other and thus are not separately identified in the usual "distance regressions." Finally, allowing for this interaction effect, renders the border coefficient statistically indistinguishable from zero in the case of the mean real exchange rate, the object of study in previous studies of the border effect.
References


