Comments on "Understanding International Price Differences Using Barcode Data," by Christian Broda and David E. Weinstein (May 2008 version)

The paper estimates equations related to those in Engel and Rogers (1996), using price data collected by households that scan bar codes of products they purchase. These regressions seek to explain price dispersion of similar or identical goods across pairs of cities within the US and Canada, and for cross-border city pairs. The data in this paper is for purchases in 23 cities in the U.S. and 6 regions in Canada. The main conclusion of the paper is that, in contrast to the conclusion reached by Engel-Rogers (ER), the "border" effect is not large. That is, while there is statistically significantly larger price dispersion for cross-border city pairs than for within-country city pairs, the paper concludes that the economic significance of the difference in dispersion is small.

Background

Both ER and Broda-Weinstein (BW) estimate equations of the general form:

$$\left\| p_i^k - p_j^k \right\| = \sum_{\ell=1}^{n} \alpha^k(\ell) D(\ell) + \beta^k d(ij) + \gamma^k B$$

In this regression, the dependent variable $\left\| p_i^k - p_j^k \right\|$ is a measure of the difference in the log of the price of good *k* in city *i* relative to city *j*. $d(ij)$ is a measure of the distance between cities *i* and *j*. *B* is the border dummy variable that takes on the value 1 if cities *i* and *j* are in different countries and zero otherwise. $D(\ell)$ is a dummy variable that takes on the value 1 if *i* or *j* equals ℓ, and zero otherwise.

In ER, prices are measured as price indexes. They are aggregated (or disaggregrated, depending on your perspective) into 12 categories such as Food at Home, Food Away from Home, Alcoholic Beverages, Men's and Boy's Apparel, Women's and Girl's Apparel, Footwear, etc. The 12 categories in ER essentially exhaust all consumer prices. The indexes are calculated by BLS for 14 US cities and by Statistics Canada for 9 Canadian cities. Canadian data is monthly. For some US cities data is monthly and for others bi-monthly. The data are from September 1978 – December 1994.

ER's measure of price dispersion is the standard deviation of the two-month difference in $p_i^k - p_j^k$. Their measures of $d(ij)$ are the log of distance between cities, a quadratic function of distance between cities, and a piecewise linear function of distance.

As noted above, BW collect data for each city from scans of UPC codes of purchases of households in each city. BW also estimate this equation for aggregated measures, and their main discussion is comparing the empirical results for the equation estimated with the most disaggregated measures to those estimated using aggregates.

BW use the absolute value of $p_i^k - p_j^k$ (or its square) in some regressions, and then, for comparability to ER, use the standard deviation of the first difference in $p_i^k - p_j^k$. Note that the first set of regressions (in levels) uses data only from the 4th quarter of 2003, while the second set of regressions (in standard deviations) uses data from (I think) 2001:Q1 to 2003:Q4. BW use the log of distance for $d(ij)$.

BW do not describe the set of goods covered by their data, except to note that it covers 128 product groups, which they describe as being in the "grocery, drug, and mass merchandise sectors."

Note that ER run a separate regression for each of their 12 "goods". BW include all goods in a single regression. In other words, they impose α^k is the same for all *k*, and likewise for β^k and γ^k. This restriction was tested and strongly rejected by ER.

1. Economic Significance

In all of the regressions run by BW, the border coefficient was very statistically significance. In the regressions using fully disaggregated absolute price level differences , the t-statistics range from 22.3 to 242.2. In the regressions using aggregated price level differences, the t-statistics range from 9 to 60.2. In the "ER type" regressions using disaggregated data, the t statistics range from 2.5 to 3.1, and using aggregated data from 5.19 to at least 1200. These large t-statistics are similar to those reported in ER, which range from around 50 to 300.

But the point of BW is interpreting the economic significance of the statistics. Their method is to compare the border coefficient, γ, to the distance coefficient β. I will return to this measure below under the heading "Using Border Width to Measure Economic Significance". Here I take a more structural view.

Suppose in city A, the price of a 10 oz. can of Coke is 45 cents and the price of a 300 ml (10.14 ounces) can of Coke is 55 cents. In city B, the 10 oz. can of Coke is 55 cents and the 300 ml can of coke is 45 cents. Is there an important price difference between these cities? Most of us would say no. We would think that people in city A could buy the 10 oz. can of Coke and people in B could buy the 300 ml. can of Coke, and they could forego the other size.

The question remains why price differences like these would exist with positive purchases of both types. I will return to that issue a couple of times below (especially under the heading "Why Prices of Brands Differ among Cities".)

How do we formalize the idea that such a price difference between cities is not important? I would argue that welfare is the right measure. A given consumer would be practically indifferent between the menu in City A and City B. Why? Because a 10 oz. can of Coke is a very close substitute for a 300 ml. can of Coke (for most consumers. Again, see below on why price differences might exist.) Welfare would be affected more if we saw this type of price dispersion among products or product groups that were not close substitutes.

BW use UPC prices, so a 10 oz. can of Coke and a 300 ml. can of Coke are different goods. By their measures, City A and City B have very different prices since the average absolute price difference is around 20 percent.

How could we get a welfare based measure of price differences? We could use welfare-based price aggregates. For example, we might posit a tiered utility function: Aggregate consumption is a CES function of the 12 categories of goods covered in ER. Each category is a CES function of a number of what BW call products. Clearly the elasticity of substitution among ER categories is lower than the elasticity of substitution among BW products. Each BW product is, in turn, a CES aggregate of a very large number of goods differentiated by UPCs. This elasticity of substitution may be much larger than the elasticity of substitution among products. For example, UPCs are differentiated by the size of the container, by whether the label has only English or French and English, etc.

To assess welfare, we could estimate the weights and elasticities in each of these price indexes. Here is what a CES price index looks like:

$$P = f(n)\cdot\left(\sum_{j=1}^{n}\left(\omega_i P_i^{1-\theta}\right)\right)^{\frac{1}{1-\theta}}.$$

θ is the elasticity of substitution, ω_i is the weight of good *i* (the weights sum to one), and $f(n)$ is a function of the number of goods available which determines the "love of variety".

If we could estimate the parameters of the CES functions at the levels of ER categories, products, and UPCs, we could directly measure the welfare consequences of price dispersion among US and Canadian city pairs. However, there are several reasons why I think that might be very hard to do: The main reason is lack of sufficient data on prices and quantities sold of each UPC in each city.

The second reason is that there needs to be a long enough time series to estimate long-run elasticities. However, there are interesting and difficult questions for assessing the welfare costs of price dispersion when long-run and short-run price elasticities differ. Do consumers face costs of adjusting their consumption basket? Is their habit persistence? If so, are preferences time-consistent? Each of these issues leads to knotty problems for assessing the welfare effects of price dispersion.

Consumer heterogeneity is another important issue. I will argue below that consumer heterogeneity plays an important role in understanding the price observations. But then to assess aggregate welfare, we cannot assume a representative consumer in each city.

Given the difficulties of doing exactly what we want, what could be done to approximate an economically meaningful answer? A start would be to assume consumers are homogeneous within each city. Then we could take meaningful guesses about the elasticity of substitutions at the different levels of aggregation. However, measuring the weights ω_i is a different problem, to which I will return.

Even if we did this, the welfare effects of price dispersion is certainly model dependent in general equilibrium because welfare depends on the supply response to prices. We could learn from a relatively simple approach which I sketch here: Suppose consumers in each location have identical tastes and income but face the menus represented by the prices measured in each city. If a UPC is not sold in a particular location, its price is infinite. Calculate the consumption basket in each city and measure the sum of the welfare of each agent. Then ask what the welfare gain would be if a planner allocated the basket of goods that was purchased in a way that maximized the sum of utility.

But if we cannot directly measure the parameters of the welfare function, I would argue that we learn more simply by aggregating prices up from the UPC level to the product level. That is, rather than comparing prices of specific brands of eggs (Broda Farms eggs, Weinstein Meadows eggs, etc.) across cities, we can just compare the price of a dozen eggs. We construct the egg price index and compare those. At the product level, the welfare cost of price differences across city pairs must be much larger than at the UPC level, because the elasticity of substitution among products is much lower than the elasticity of substitution among UPCs within a given product category.

BW report statistics from regressions at the product level of aggregation in Table 4 for price level data, and find an economically significant (by their measure) welfare effect. BW describe the difference between the Table 4 results and the Table 3 results using UPC prices as an aggregation bias. But since I would argue that the Table 4 results come closer to a measure of the border that is relevant for welfare, the regressions in Table 3 display a "disaggregation bias". What I mean precisely is that the measure of the border effect BW develop from the regressions of Table 3 does not represent an economically meaningful statistic. The fact that the border effect is small does not mean that it is economically insignificant.

BW might argue that UPC level goods are not really close substitutes. On page 17, for example, they talk about how a product category like "fresh eggs" might aggregate different types of eggs that are not close substitutes: "If categories like "fresh eggs" are very heterogeneous, then a basket of fresh eggs in one country is likely to contain very different eggs than a basket of eggs in another country." I firmly believe that different brands of fresh eggs are usually close substitutes, but let me not insist on that. I do want to note that if we find on the same grocer's shelf a dozen large eggs selling for \$1.98 and a dozen jumbo organic eggs selling for \$2.47, that alone is not evidence that different eggs are not high substitutes. Obviously those two types of eggs have different characteristics, but the issue is whether, in essence, consumers think the jumbo organic eggs are always just about 25% better than large regular eggs. That is, if the price ratio changes much from 2.47/1.98, is there a large change in quantities bought of each? Unfortunately, that is what I have argued above is difficult to measure.

But let's grant the BW case that these are not close substitutes. In that case, Figure 2 actually provides evidence of an economically large border effect. That Figure shows that the set of UPCs sold in common across two typical cross-border city pairs is a much smaller percentage of all UPCs sold than for a typical within-country city pair. On page 11, BW state "In the typical bilateral city/region comparison between the US and Canada, only 7.5 percent of the goods are common, this is less than one third the common set of goods available between city pairs of equal distance within the US." Broda and Weinstein (2004, 2006) estimate the welfare effects of freer trade by calculating the welfare gains to consumers from greater variety availability precipitated by trade. If UPC goods have as low elasticities as estimated for products in the Broda and Weinstein (2004, 2006) papers, the effect of the border is huge in welfare terms. The effect of the border is to exclude a large number of varieties from consumption baskets. This effect is also evident in the large differences in the border effect estimated when BW use price indexes across all UPCs rather than using prices from the set of UPCs that is common across each city pair.

As I said, I actually suspect that the UPCs within each product are high substitutes, but there are two reasons why I would not conclude that the regressions of Table 4 are satisfactory for demonstrating that there is a significant border effect.

First, our concern ultimately is whether there are economically significant price distortions across cities. The problem with looking at aggregates is that the price aggregates can differ across cities not just because prices differ but also because preferences differ. One way to get around this is to use a price aggregate that has a common set of weights for aggregating prices in each city. With these we could measure the welfare cost to a pair of mythical identical consumers who are confronted with the menus in two different city pairs. So a great advantage of the BW data is that they could construct such data. ER use the BLS aggregates for US prices, which I think use the same weighting scheme across cities, so they would accomplish the same goal. However, the key point is that ER's cross-country comparisons use price indexes aggregated in different countries. If price index weights differ across countries, ER's price differences may reflect taste differences between countries (which I believe is what BW are trying to say) rather than actual price differences. With BW's data, we could construct indexes for a given hypothetical consumer and can confront consumers with price menus for different cities within a country and across borders.

The first panel of Table 4 does use equal weights across cities, but excludes any UPCs that are not common. But for welfare purposes, the right price index is the utility based one that aggregates across all goods. The price of goods not sold in one city is taken to be infinite under CES preferences, but that large price would not matter much for welfare if it is for a good that is a close substitute for another that is sold in the city. For example, if city A sells Broda Farm eggs for $2 but does not sell Weinstein Meadows eggs at all, and city B sells Weinstein Meadows eggs for $2 but not Broda Farms eggs, the right welfare comparison is to use a price index that has both of these goods in both cities with equal weights. They are very close substitutes, so that the fact that Weinstein Meadows eggs have an infinite price in city A does not matter much for welfare.

Second, the price indexes constructed for Table 4 are not the correct welfare-relevant price indexes. They are Cobb-Douglas price indexes, which are appropriate when the elasticity of substitution is equal to one among brands. Suppose that City A and B both sell 10 oz. and 12 oz. cans of Coke, but in City A, 99% of Coke expenditure is on the 10 oz. size and in City B 99% is on the 12 oz. size. Suppose in both cities, the 10 oz. size costs 50 cents and the 12 oz. size costs 60 cents. Assume further that the share of total expenditures on Coke is 10%, and that the price index of all other goods, P_0 equals one in both cities. Then the price index in each city as calculated in BW:

$$P_A = P_0^{.9} P_{10}^{.099} P_{12}^{.001} = 1^{.9} .5^{.099} .6^{.001} = .9332$$

$$P_B = P_0^{.9} P_{10}^{.001} P_{12}^{.099} = 1^{.9} .5^{.001} .6^{.099} = .9500$$

City B's price index is almost 2 percent higher than A's under this calculation (and the Coke price index difference is about 20%), though most of us would agree that the actual welfare-based price difference is very small since 6 cans of 10 oz. Cokes are highly substitutable for 5 cans of 12 oz. Cokes. The correct welfare based price indexes would not show a difference.

The problem with constructing the welfare based price index is measuring the ω_i. How do we weight a dozen large regular eggs compared to a dozen jumbo organic eggs? How do we weight Coke and RC Cola? I think it is hopeless to try to undertake that exercise with any data set I could plausibly envision.

But a first-order log approximation to the price index for any homothetic utility function is the expenditure weighted sum of the log of prices. We cannot compare price levels across cities (because that requires measuring the price level at the point of approximation), but we can compare changes in log price levels. As noted above, my preference would be to compare indexes with equal weights across cities. But probably the price indexes calculated by BW using all goods and city-specific expenditure shares are pretty good for comparing changes in price indexes.

For example, suppose City A sells eggs only by the half-dozen and dozen and City B only by the two dozen and three dozen. It is hard to know how to construct a utility index of eggs that can allow us to compare the average price in City A and City B. But if the expenditure weighted price index rises by 10% in each city, that is a good approximation of the change in the percentage change in the welfare-based price index.

The obvious drawback in comparing changes in price levels is that prices in City A and City B could be moving in opposite directions because the levels are converging or because they are diverging at any point in time. But the correlation of changes in p_i^k with p_i^j is a measure of the average comovement of the two prices and is particularly apt if the price processes are linearly. If the variances of changes in p_i^k and p_i^j are equal, then for comparison across city pairs the variance of the change in $p_i^k - p_j^k$ provides the same information as the correlation since $\text{var}(p_i^k - p_j^k) = 2\sigma^2(1-\rho_{ij}^k)$, where σ^2 is the variance of the changes in the price levels and ρ_{ij}^k is the correlation of changes in p_i^k with p_i^j.

Table 6 uses exactly the variance measure of price changes. The second panel uses all goods and city-specific weights. The border effect measured there is enormous (by BW's measure), but that may not represent "aggregation bias". This may be the measure of prices most relevant for welfare. In short, I conclude that the most economically meaningful estimates in the paper are the ones that end up giving us the largest border effect.

BW give a mechanical explanation of why the border matters more for the aggregate price level than when disaggregated UPC prices are used in the Engel-Rogers type regressions. However, I think there is an economic explanation, which is related to why UPC prices are so different across cities within countries.

2. Why Prices of Brands Differ Among Cities

A thorough theoretical explanation of why very similar brands have very different prices across cities within the same country is the subject for a different paper. But I do think it is worth speculating on this briefly because it matters for considering the economic significance of the border effect.

My reading is that a lot of the difference in relative prices p_i^k / p_i^ℓ compared to p_j^k / p_j^ℓ (the price of good *k* relative to good ℓ in city *i* compared to city *j*) occurs because there is not a single homogenous consumer in each city. Let me give two examples.

As far as I can tell, Miller beer and Lone Star beer are the same. They are perfect substitutes for almost everybody. Miller is brewed in Milwaukee and Lone Star in Texas. Since it is costly to ship beer, I would not be surprised to see a lot of Miller sold in Milwaukee and a lot of Lone Star in Texas. If a six pack of Lone Star sells for the same price in Texas as a six pack of Miller in Milwaukee, I would conclude there is no welfare loss from the fact that beer is costly to ship. But Lone Star is also sold in Milwaukee. I think it is sold as a specialty beer to that small minority of consumers who think it has some characteristic that makes it different than Miller (such as the fact that it has the lone star on the label.)

A more general example comes from my reading of Nakamura (2008) and Eichenbaum, Jaimovich, and Rebelo (2008). I conclude from those papers that there are a lot of price changes that are not related to the state – to either shifts in demand or costs. Instead they represent what Nakamura calls "pricing dynamics". Essentially these are like sales – price changes that help discriminate among low elasticity and high elasticity consumers. If sales occur at different times in different cities based on strategic considerations but not based on demand or costs shifts, prices of brands may differ across cities.

Under plausible assumptions, neither of the price differences that I describe above matter much for welfare. On the other hand, apparently prices of identical brands across the US and Canada vary because their local currency prices do not vary much but the exchange rate varies a lot. This is the mechanical description given by Broda and Weinstein in equations (14)-(16). That is, price variation of brands across cities within a country is random and not correlated across brands (such as my sales example.) But price variation across brands between US and Canadian cities is correlated across goods because it moves with the exchange rate.

The key point is that if the prices of all goods in one city are moving against the price of all goods in another city, the welfare effect could be very large. The welfare effect can be much larger than if prices of brands are varying a lot but the price aggregates are not varying much.

3. Using Border Width to Measure Economic Significance

BW measure economic significance by "border width". This is a nonlinear comparison of the coefficient on the border, γ, to the coefficient on log distance, β, specifically $\exp(\gamma / \beta)$. BW express this measure as the economic significance of the border as captured by the "border width" measured in miles.

But this makes no sense. Since distance is measured in logs, the effect on price dispersion of going from 1 inch to 2 inches is the same as 1 mile to 2 miles and the same as going from 1000 miles to 2000 miles. So we cannot compare the effect of crossing the border on price dispersion to the effect of log distance measured in miles by this measure.

ER use this measure, but subsequent work has pointed out that it is meaningless. BW recognize this and acknowledge this, but use it anyway. The working paper version of ER (Engel and Rogers, 2004) uses a measure of border width that is not subject to this particular problem.

The obvious numerical effect of calculating $\exp(\gamma / \beta)$ is that it blows up the comparison of γ / β. For example, in Table 4, using absolute log price difference, going from the common weighted index of common goods to the city specific weighted index of all goods raises the estimated value of γ / β from 3.2 to 16.95. That is a dramatic rise. But when expressed as border width, $\exp(\gamma / \beta)$, it is a change from 25 "miles" (or nanometers) to 23 million "miles" (or nanometers.) That little trick is a double-edged sword for BW however. Later (under the heading "Using Only 2003:Q4 Data") I argue that using data from a different quarter could increase the border coefficient by as much as a factor of 7.5, probably without changing the coefficient on distance. The effect on "border width" would be dramatic. Even the border measured as 25 miles above would increase to 265 *billion* miles. I hope these examples illustrate how hopeless it is to take "border width" as calculated by BW seriously as a measure of economic significance. But the exposition of the paper relies on the reader taking it seriously.

How can we calculate economic significance? Above I suggest using a welfare measure, but that depends on measuring the parameters of the utility function which may be difficult. The idea of the border measure is to compare the effect of the border barriers to within-country barriers. But that idea deserves more thought.

In the first place, the coefficient on distance is probably not a great way to summarize the effects of within-country barriers. Log of distance is only meant to be a proxy for describing factors that lead to price differences among cities within countries. One issue from a welfare standpoint is how to assess the fact that New York prices in the "grocery, drug, and mass merchandise sectors" are probably fairly uniformly higher than in Minneapolis. Do we want to consider that a barrier to trade, or something else?

If we want to use the border dummy to measure the effect of market segmentation between Canada and the US, we cannot use explanatory variables for price differences within countries that would capture market segmentation across countries. Engel (2002) notes that some studies attribute price differences to differences in local wage costs. But if we compare Canadian and US wages using $S_{\$US/\$CA}W_{CA}/W_{US}$, where W_{CA} measures Canadian wages in Canadian dollars and W_{US} measures US wages in US dollars, then we have a problem. If the border effect is a reflection of local-currency price stickiness, then $S_{\$US/\$CA}W_{CA}/W_{US}$ might vary because of local-currency wage stickiness – most of the variation comes about because of variation in the nominal exchange rate $S_{\$US/\$CA}$.

Engel (2002) does an old-fashioned "analysis of variance" to compare the significance of the border to the significance of other explanatory variables (log distance and dummy variables.) But that measure still depends on capturing well the reasons for within-country variance. Maybe more revealing would be simply to measure the variance of relative prices explained by the border dummy to the overall unconditional variance of the relative prices.

But all in all, this is an area where some creativity could certainly produce more interesting measures of the economic significance of the border.

4. Homogeneity Assumption

As noted above, BW lump all goods into a single regression, which imposes the constraint that the coefficients on the border dummy, log distance, and city dummies is the same across all goods. No other paper in the literature does this, and ER report that this restriction is "strongly rejected". BW should at least allow the coefficients to differ for different products, if not for all UPCs.

If we use the last measure of the border effect that I propose above – the amount of price dispersion explained by the border dummy – it certainly is important to allow for coefficient heterogeneity. (Of course, also, this measure will be larger for product price aggregates than for UPC prices, and I contend the product price aggregates are the most relevant.)

5. Using Only 2003:Q4 Data

The summary statistics reported in Table 2, and the regressions comparing price levels in Tables 3 and 4 apparently use data only from the 4th quarter of 2003. Table 2 reports that the standard deviation of price levels between US and Canadian cities is only 2.67%, not too much more than the standard deviation of within-country pairs in Canada and the US, and that the median price difference is 2.1%. But footnote 13 implies that if we look at all of the quarters for which BW have data, the cross-country price "fluctuations" range from 2% to 15%. (It is not clear if "fluctuations" means median price difference or standard deviation.)

That is, it appears that 2003:Q4 is a quarter with atypically low cross-border price differences. PPP differences may have been at their lowest in the past twenty years. Suppose instead BW picked a quarter in which the price difference was 15% instead of 2%. I think that would push up the border coefficients by a factor of 7.5, but there is no reason why it would affect the distance coefficient. But just this change alone would raise all the "small" border coefficients in Table 3 – 720 miles, 328 miles, 106 miles, 36 miles – dramatically to 2.7 ***sextillion*** miles, 7.4 ***quintillion*** miles, 1.5 ***quadrillion*** miles, and 470 ***billion*** miles, respectively.

Of course these border width measures are meaningless, as I have already explained. But BW use the border width measure to demonstrate economic significance. They compare favorably their seemingly reasonable border width estimates to the very large border width numbers reported in studies such as 43 quadrillion miles in Parsley and Wei (2001).

6. Within City Price Dispersion

BW's data comes from prices scanned by households from their purchases of goods at the various places that they shop. The data is not described in detail. (The paper would be improved if it described the data in more detail, gave an appendix table that listed the products covered, and for each table of regression results reported the data range that was used.) I believe, however, that to get the price for a given UPC for a city for each quarter, BW average over all the entries of that UPC. That means that for a given city, their data has prices recorded at different dates within the quarter, and at different outlets.

By contrast, the BLS samples prices during a fairly narrow pricing window each month. It does average prices over outlets, but stratifies the sample so that the price sample reflects comparable outlets across cities. (I am fuzzy, however, on the exact details of how they do this.)

It is hard to tell if the price samples in the BW data are really comparable across cities. In the US, the data come from approximately 2600 "demographically representative" households per city, and approximately 2500 households per region in Canada. Maybe we can appeal to the law of large numbers to hope that on average we are comparing prices from comparable outlets collected at comparable times across cities. But it is hard to know.

One interesting tidbit is that Gopinath, Gourinchas, and Hsieh (2008) seem to find much less within-country price heterogeneity using UPC prices from a single chain.

It would be helpful if BW could parse their data more. Can they produce prices collected in a narrower window? Can they use a store identifier to compare prices of goods sold at comparable outlets?

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