

International Prices, Costs, and Markup Differences[†]

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Relative cross-border retail prices, in a common currency, comove closely with the nominal exchange rate. Using product-level prices and wholesale costs from a grocery chain operating in the United States and Canada, we decompose this variation into relative costs and markup components. The high correlation of nominal and real exchange rates is driven mainly by changes in relative costs. National borders segment markets. Retail prices respond to changes in costs in neighboring stores within the same country but not across the border. Prices have a median discontinuous change of 24 percent at the border and 0 percent at state boundaries. (JEL F31, L11, L81)

A well-established fact in international economics is that relative prices at the retail level across countries, expressed in a common currency, comove closely with the nominal exchange rate. Understanding why is central to answering some of the classic questions in international economics, ranging from the gains from market integration to the transmission of shocks across borders. Two ingredients are necessary to generate this pattern in the data. First, some economic forces must cause retail prices to differ across countries. Standard explanations emphasize the importance of local nontraded retailing costs or pricing to market at the retail level (Ariel Burstein, Martin Eichenbaum, and Sergio Rebelo 2005; Pinelopi K. Goldberg and Frank Verboven 2005). Second, cross-border transaction costs must be large enough to prevent arbitrage. Indeed, a large body of literature interprets the price gap of similar goods across borders as a measure of these transaction costs (Charles Engel and John Rogers 1996).

In this paper, we bring new data and a new approach to these questions. We use weekly data at the barcode level on retail prices and wholesale costs for 250 US stores (in 19 states) and 75 Canadian stores (in 5 provinces) of a single retail chain between January 2004 and June 2007 on over 4,000 products. At short horizons

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these wholesale costs are the relevant marginal costs for retailers. We use these data to measure directly the extent to which cross-border retail price differences arise because of wholesale-level pricing to market or because of variations in retail markups. In the absence of systematic cost data, the literature has been limited to a few studies of specific goods, such as beer (Goldberg and Rebecca Hellerstein 2007) and coffee (Emi Nakamura and Dawit Zerom 2010).¹ These studies examine a narrow set of products, however, and focus on one market at a time (the United States). Therefore, they do not speak directly to the issue of international price differences. By contrast, our data contain information on retail prices and wholesale costs for multiple products sold by a single retailer in the United States and Canada.

Our findings are as follows. First, we establish that differences in retail prices and wholesale costs are larger across the US-Canadian border than across stores located within the same country. Second, we find that, unconditionally, both wholesale cost gaps and markup gaps contribute to the variability in price gaps. Across products the median contribution of net costs to relative price variability ranges from 55 percent at the weekly horizon to 77 percent at the quarterly horizon. Third, the variation in cross-border retail prices conditional on changes in the nominal exchange rate between US and Canadian stores is driven entirely by the variation in relative wholesale costs. This new finding suggests that the correlation between the nominal and real exchange rate for the goods in our sample is not driven by local nontraded costs such as wages or by pricing to market at the retail level, but rather by pricing to market at the wholesale level.

Next, we measure the extent of market segmentation between Canada and the United States. We provide new estimates of the size of the border costs—i.e., the *additional* transaction costs incurred when markets are located in different countries—at the retail level. A large literature, starting from the seminal contribution of Engel and Rogers (1996), estimates border costs from price gaps of similar goods across borders.² Two issues need to be addressed, however, before price gaps can be interpreted as border costs. First, cross-border price gaps are also affected by local transaction costs and differences in local market conditions. These factors would also result in cross-border price gaps even if the border cost were zero.³ Second, the logic of using price gaps to infer trade costs implicitly assumes that markets remain integrated despite these transaction costs. This, however, begs the question of whether transaction costs are large enough to segment markets and whether international markets are more segmented than domestic markets.

¹In other cases, in the absence of cost data, markups are structurally estimated using price and quantity data, and a flexible demand structure, as in Goldberg and Verboven (2001, 2005) who study the automobile car market in Europe.

²Engel and Rogers's (1996) work has been followed up by many authors. Mario J. Crucini and Mototsugu Shintani (2008) and Crucini, Chris I. Telmer, and Marios Zachariadis (2005), for instance, examine the retail price of narrowly defined product categories, such as "washing powder," across countries within the European Union. Others focus on specific goods, such as *The Economist* magazine (Atish R. Ghosh and Holger C. Wolf 1994), Ikea's furniture products (Jonathan Haskel and Holger Wolf 2001; Wolter H. J. Hassink and Ronald Schettkat 2001), or Scandinavian McDonald's *duty-free* outlets (Marcus Asplund and Richard Friberg 2001).

³A solution proposed by Engel and Rogers (1996) is to control for these other factors by measuring cross-border price gaps relative to price gaps between markets in the same country. Yuriy Gorodnichenko and Linda Tesar (2009) point out, however, that this approach is valid only if heterogeneity in transportation costs and demand is of similar magnitude between all countries.

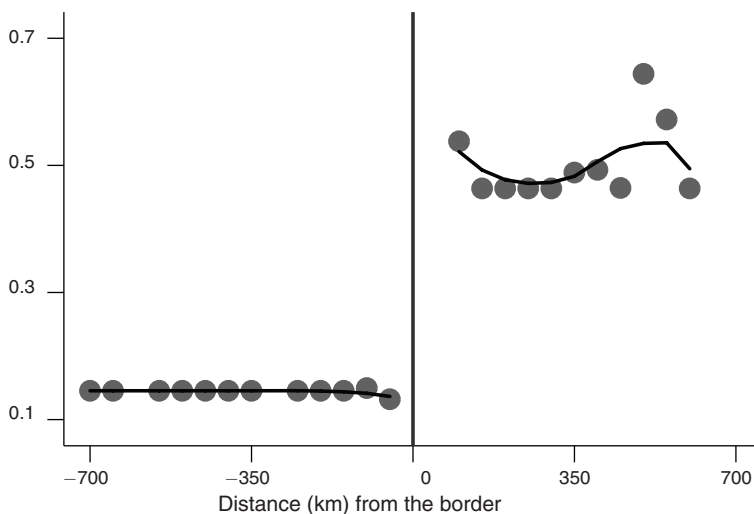


FIGURE 1. GRAPHICAL DEPICTION OF BORDER DISCONTINUITY FOR PERRIER SPARKLING MINERAL WATER
(First week of 2004)

Notes: Perrier Sparkling Natural Mineral Water, 25-ounce bottles. Store distance to the border is positive for the United States, negative for Canada.

Instead of looking at price gaps per se, the approach we take to measure the extent of market segmentation is to evaluate the response of prices in one market to cost shocks in neighboring markets. It is immediate that the response will depend on the extent of market segmentation. When markets are integrated, prices in a given market will be affected by cost shocks in other markets. When markets are segmented, prices will be only a function of costs and demand in their own market and will not respond to cost shocks in other markets. Using our data on retail prices and wholesale costs across stores, we find that controlling for the store's own wholesale costs, an increase in wholesale costs in neighboring markets of 1 percent increases the store's retail price by 0.12–0.13 percent when the neighboring store is in the same country. In contrast, prices do not change in response to changes in wholesale costs of neighboring stores when the neighboring store is in a different country. These findings suggest that domestic markets are likely to be integrated while international retail and wholesale markets are not. The fact that international markets are segmented immediately implies that cross-border price gaps will provide us only with a lower bound estimate of border costs.

We then estimate this lower bound using a regression discontinuity design. Our data provide the precise geographic location of the store, which we use to answer the following question: what is the magnitude of the deviation from the law of one price between stores located right across the border from each other? To illustrate the nature of our evidence, Figure 1 plots the (log) average price across stores (in 50-kilometer bins) for 25-ounce bottles of Perrier Sparkling Natural Mineral Water against the individual store's distance from the border. There is a clear price discontinuity at the border. We find evidence consistent with the discontinuity in Figure 1 in our broader sample of products: the median absolute price discontinuity is 24 percent for consumer prices and wholesale costs across our sample of matched products. In contrast, at the Washington-Oregon border this discontinuity is 0 percent for consumer prices and wholesale costs.

This paper builds on several bodies of work. Our decomposition of retail prices into markups and wholesale costs builds on the findings of Goldberg and Hellerstein (2007) and Nakamura and Zerom (2010) that pricing to market at the wholesale level is key to understanding the correlation of nominal and real exchange rates. Christian Broda and David E. Weinstein (2008) also examine retail price data for individual products defined by their Universal Product Codes (UPCs). Our data, however, come from a single retailer in all locations, whereas Broda and Weinstein (2008) compare the price at which different consumers purchase a particular good without controlling for the fact that these consumers purchase that good from different retail establishments.⁴ Further, we have information on wholesale costs. The approach we take departs from Engel and Rogers (1996) and the existing literature in that it explicitly tests for market segmentation and uses a regression discontinuity approach to estimate a lower bound on the border cost. Finally, Burstein and Nir Jaimovich (2008) also examine the pattern of wholesale prices in the United States and Canada using the same dataset. Unlike us, these authors do not decompose variation in retail prices into costs and markups, and do not compare intra- versus international price differences.

The paper proceeds as follows. Section I describes the data. Section II presents evidence on price gaps and an unconditional variance decomposition of these price gaps into costs and markups. Section III evaluates the conditional response of price gaps and cost gaps to exchange rate shocks. Section IV presents evidence on international versus domestic market segmentation. Section V discusses estimates of border costs using the regression discontinuity approach, and Section VI discusses the interpretation of our results on wholesale costs.

I. Data Source

We have access to weekly product-level data for 325 grocery stores in the United States and Canada (250 stores in 19 US states and 75 stores in 5 Canadian provinces) operated by a single retail chain.⁵ Figure 2 plots the location of the stores in our data. Most US stores are located in the western and eastern corridors, in the Chicago area, Colorado, and Texas, while most Canadian stores are located along a relatively narrow horizontal band running close to the border with the United States. The dataset contains information for 125,048 unique products (UPCs) sold in these stores between January 2004 and June 2007 (178 weeks). Most of the products are in the food and beverages categories, housekeeping supplies, books and magazines, and personal care products.⁶ This level of disaggregation allows for a very precise identification of products. For instance, in our data, a 25-ounce Perrier Mineral Water with a Lemon Twist and a 25-ounce Perrier Mineral Water with a Lime Twist are two separate items in the soft beverages product group.

⁴Broda, Ephraim Leibtag, and Weinstein (2009) show that price heterogeneity across retailers is attributable in part to differences in shopping experiences and amenities provided by different retailers.

⁵This chain is one of the leading food and drug retailers in the United States and Canada and operates directly or through subsidiaries a total of 1,400 stores in the United States and 400 in Canada. The data-sharing agreement between this retailer and the research community is managed through the SIEPR-Giannini data center (<http://are.berkeley.edu/SGDC>).

⁶Appendix Table A2 reports a breakdown of UPCs by product categories.

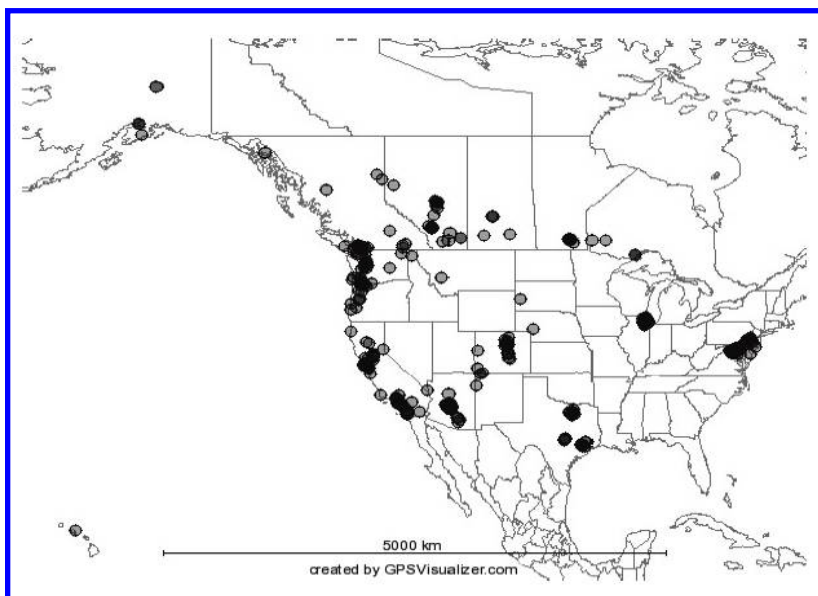


FIGURE 2. MAP OF THE 325 NORTH AMERICAN RETAIL STORES (250 US AND 75 CANADIAN)

The three key pieces of information we use from the data are the price, the wholesale cost, and the marginal cost of each product (for every store and every week). The retailer reports “gross” and “net” revenues for each product-store-week. Gross revenues refer to revenues computed at the retail list price, while net revenues measure revenues net of rebates, promotions, and coupons. We construct corresponding gross and net prices by dividing revenues by quantities.⁷

As for the costs, our dataset includes two pieces of information. The retailer reports the “wholesale cost” which is the list price of the product at the wholesale level (vendor cost). The dataset also reports “adjusted gross profits” per unit for each product, defined as the net price minus the sum of wholesale costs and transportation costs plus net rebates from the manufacturer.⁸ We subtract these adjusted gross profits from the net retail price to back out the “net cost” of each product. The precise link between the wholesale cost and our imputed net cost is as follows:

$$\begin{aligned} (1) \text{ Net cost} &= \text{Wholesale cost} + \text{Freight and transportation costs} - \text{Net rebates} \\ &= \text{Net price} - \text{adjusted gross profit.} \end{aligned}$$

⁷Both the gross and net retail price exclude US sales as well as Canadian federal value-added taxes (VAT) and provincial sales taxes. From a consumer’s perspective, the relevant price is the price inclusive of sales taxes and VAT. We do not have this tax information, which varies by UPC and location both within and across countries. For instance, many food products are exempt from sales tax both in the United States and Canada. In general, we found that sales taxes and VAT are higher in British Columbia (13 percent) as compared to Washington State (around 8 percent). To the extent that before-tax prices are higher in Canada than in the United States, as we find for a majority of goods in our sample, this implies that the after-tax price gap between the two countries is larger than what we measure. More important, since the VAT and sales tax remained more or less constant over time, they cannot explain the pattern of comovement with exchange rates that we observe in the data.

⁸Specifically, adjusted gross profits is defined as net price minus wholesale cost plus “total allowances.” The documentation provided by the retailer defines total allowances as “the sum of shipping allowances, scan allowances, direct-store-delivery case bill back allowances, header flat allowances, late flat allowances, and new item allowances, minus the sum of buying allowances, freight allowances, overseas freight, and distress and other allowances.”

It is important to note that neither measure of costs includes local costs (such as labor, rent, and utilities) at the store level. At short horizons, with rent, capital, and labor taken as given, it is natural to interpret the net cost as the full marginal cost of the product faced by the retailer and the net price as the actual price of the product. Unless specified otherwise, our empirical analysis refers to net prices and net costs.⁹

Our first task consists in restricting the initial sample of 125,048 unique products to a set of products that appears on both sides of the border in at least one week. This matched set represents the set of goods for which we can evaluate deviations from the law of one price (LOP). It contains 4,221 unique products, or about 3.3 percent of the original dataset.¹⁰ This decline in matched products across the border is an important effect emphasized in Broda and Weinstein (2008), which carries across to our dataset and underlies the importance of working with unique products.

One concern is that otherwise identical goods have different UPCs because of different labeling requirements in the United States and Canada (for example, language and nutritional information), so that only goods with common labeling would be included in our matched sample. To assess this possibility, we visually inspected the labels of our matched UPCs in a store in the United States (Oakland, CA) and in Canada (Vancouver, BC). We found identical physical characteristics for all matched products, but often different labels in the two countries. Thus, it seems that different labeling does not necessarily imply different UPCs.¹¹

The set of matched UPCs is concentrated in books and magazine (2,505), alcoholic beverages (403), ethnic and gourmet food (306), and household cleaning products (159).¹² The distribution of goods across product groups is very skewed, with a median around 11 and a mean of 97.¹³ Panel A of Table 1 reports information on the number of distinct products (among matched goods) per store-week and per store-pair-week in our data. The average US store in the data carries 493 distinct matched products for which we have data in a typical week. We find about 272 (251) matched products for a typical within-country store pair in the United States (Canada) in a given week, and 167 for a cross-border store pair.

Finally, we link the precise geographic coordinates of each store to data from the Canadian and US censuses to measure the characteristics of the local market served by each store.¹⁴ Panel B of Table 1 provides some summary statistics for these local market characteristics. The median store in our sample is located in an area with a population density of 810 persons per square kilometer in the United States, with a

⁹Our results are qualitatively unchanged if, instead, we use gross prices and wholesale costs.

¹⁰We arrive at this number in the following way. We start with the set of unique UPCs that appears in at least one US and one Canadian store (6,343). We check the product descriptions to ensure that the products are identical (6,283). We further drop UPCs with fewer than ten digits since these are generated internally by the retail chain and may not be consistent across countries (5,900). We further eliminate products in the fresh bread/baked goods, deli, food service, produce, seafood, meat, and floral arrangements categories, since these goods contain a higher local labor content and are not available in identical form in different stores (4,221 goods).

¹¹It is possible, of course, that many identical products could still have different UPCs in the two countries, which could be a factor behind the low match rate. Matching goods that do not share the same UPC is not currently feasible given the limited product information we have.

¹²“Books and magazines” have a printed sale price that is sticky in the local currency. We find that all our results are roughly unchanged if we exclude this category of goods.

¹³See table A.2 in the Appendix.

¹⁴The US data come from the US population census and economic census database. The Canadian data come from Statistics Canada. There is a difference in the level of disaggregation at which the data is collected because Canadian data are collected at the census subdivision level while US data are collected at the ZIP code level.

TABLE 1—DESCRIPTIVE STATISTICS

| | Canada | | | United States | | |
|--|---------|--------|---------|---------------|--------|---------|
| | Median | 10% | 90% | Median | 10% | 90% |
| <i>Panel A. Number of UPCs sold per store/week</i> | | | | | | |
| UPCs per store | 7,998 | 5,725 | 9,187 | 10,827 | 8,387 | 12,812 |
| Matched UPCs per store | 422 | 261 | 528 | 493 | 354 | 640 |
| Matched UPCs per store pair (within country) | 251 | 144 | 331 | 272 | 183 | 365 |
| Matched UPCs per store pair (cross country) | 167 | 98 | 225 | 167 | 98 | 225 |
| <i>Panel B. Store-level covariates</i> | | | | | | |
| Population density (persons per sq km) | 1,095.8 | 97.9 | 1,533.7 | 810.2 | 57.2 | 2,671.2 |
| Store density (stores per square km) | 0.2864 | 0.0354 | 0.8804 | 0.1492 | 0.0105 | 0.8580 |
| Median household income (\$2000 US) | 31,014 | 28,199 | 41,109 | 57,040 | 34,238 | 82,592 |
| Share of population 0–19 | 0.26 | 0.22 | 0.31 | 0.29 | 0.19 | 0.34 |
| Share of population 65 and up | 0.13 | 0.07 | 0.17 | 0.10 | 0.05 | 0.16 |
| Share of population black | 0.01 | 0.00 | 0.02 | 0.03 | 0.01 | 0.16 |
| Year store opened | 1988 | 1965 | 2001 | 1992 | 1971 | 2001 |
| Store selling area (sq feet) | 26,225 | 15,495 | 39,079 | 27,168 | 15,595 | 38,540 |
| Distance to the border (km) | 98 | 15 | 503 | 558 | 283 | 1,732 |

Notes: The table reports the median, tenth, and ninetieth percentiles across the 75 Canadian stores and 250 US stores in our sample. The variables are either provided to us directly by the retailer or derived by using store addresses to link them to ZIP code-level US census data for 2000 and census subdivision level Canadian census data for 2001. Distance is calculated using ArcGIS as the great circle distance to the Canada-US border from the geocoded latitude and longitude of the store address.

density of stores equal to 0.15 stores per square km¹⁵ and with a median household income of US\$57,040 in the year 2000. There is significant variation across the stores in our sample, with US population density ranging from 57.2 (tenth percentile) to 2,671 (ninetieth percentile) persons per square km, supermarket density ranging from 0.01 to 0.85 stores per square km, and median household income ranging from \$34,238 to \$82,592.

II. Price Gaps

This section presents three sets of summary statistics. First, we present the distribution of the gap in average prices, costs, and markups between US and Canadian stores. Second, we present the distribution of the gaps in prices, costs, and markups between all store pairs, focusing on the difference between store pairs in the same country and store pairs located in different countries. Third, we decompose the variance of average price gap between the US and Canada into a relative wholesale cost and relative markup component.

A. Cross-Border Price Gaps

We begin by presenting statistics on the deviation in prices, costs, and markups between US and Canadian stores. For every product, we compute the difference in the (log) average price in all US stores from the (log) average price in all Canadian stores. We do the same for costs and markups. Figure 3 plots the resulting distribution of cross-border gaps of the average net price, net cost, and markup for the first week

¹⁵These are establishments in the North American Industry Classification System (NAICS) 445,110 (supermarkets and other grocery stores, but not convenience stores) similar to the stores in our data.

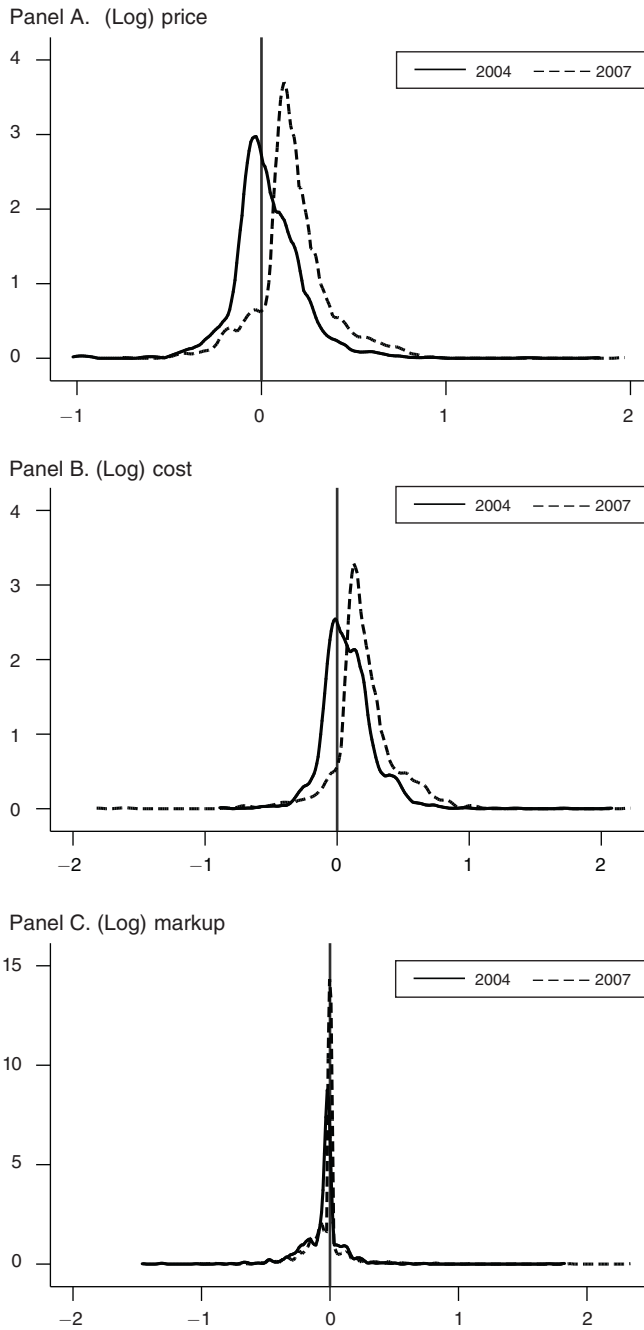


FIGURE 3. THE DISPERSION OF CROSS-BORDER AVERAGE PRICE, COST, AND MARKUP GAP

Note: 2004 refers to the first week of 2004; 2007 refers to the 21st week of 2007.

of 2004 (2,242 UPCs) and the twenty-first week of 2007 (2,267 UPCs).¹⁶ A positive value indicates that the average price (and cost or markup) is higher in Canada than in the United States. Panel A of Figure 3 shows that there is large dispersion of gaps in average prices between the United States and Canada across UPCs. For the first week of 2004, 9.9 percent (resp. 4.8 percent) of products are 25 percent more expensive in Canada (resp. the United States). By the twenty-first week of 2007, the corresponding numbers are 28.5 percent and 1.9 percent. This shift in the distribution of the average price gap reflects the appreciation of the Canadian dollar relative to the US currency between 2004 and 2007. While the cross-border price gap for any individual UPC is likely to be dominated by idiosyncratic factors, the distribution shifts in line with the exchange rate. This finding is consistent with Crucini and Chris Telmer (2007) evidence from more aggregated data.

Panels B and C of Figure 3 report the corresponding distribution of the cross-border average marginal cost gap and markup gap. The figures indicate significant dispersion in relative costs across the border, but a much tighter distribution of markup differences across the border. Between 2004 and 2007, the fraction of products with marginal costs at least 25 percent more expensive in Canada (resp. the US) changes from 14.9 to 34.9 percent (resp. 3.2 to 3.1 percent). In contrast, the fraction of products with markups at least 25 percent higher in Canada (resp. the US) varies from 2.4 to 3.7 percent (resp. 8.4 to 6.8 percent).

B. Price Dispersion across Stores

We now measure price dispersion across all the stores in our sample, focusing on the price gap between stores located in the same country versus the price gap between stores located in different countries during the first week of 2005. We have a total of 31,125 store pairs in the United States, 2,775 store pairs in Canada, and 18,450 cross-border store pairs. The median number of common UPCs that week is 260 for US store pairs, 242 for Canadian store pairs, and 170 for cross-border pairs. For all the common products in each store pair, we compute the difference in the log price between the two stores. Panel A in Table 2 presents statistics across store pairs on the mean, median, and maximum of the absolute price gap for store-pairs located in the United States (USA-USA), Canada (CAN-CAN), and across the border (CAN-USA). The median price gap across store pairs is 3.7 percent for US store-pairs, 0 percent for Canada store pairs, and 14.6 percent for cross-border pairs (col. 2). Since the US store is always treated as the store of reference, this implies that Canadian retail prices were 15 percent higher than US prices in the first week of 2005.¹⁷

The finding that the dispersion of US prices is larger than the dispersion of Canadian prices is consistent with the evidence in Engel and Rogers (1996) and Broda and Weinstein (2008). However, unlike Engel and Rogers (1996) and Broda and Weinstein (2008), we find that the dispersion in cross-border price gaps vastly exceeds that of within country price gaps. As Gorodnichenko and Tesar (2009) point out, the dispersion of prices between US city pairs in Engel and Rogers (1996) is about the

¹⁶This corresponds to the first and next-to-last week of our sample. There is a significant drop in the number of UPCs in the last week of our sample, which is why we use the next-to-last week.

¹⁷Since these are pre-tax prices, the 7 percent Canadian value-added tax (or GST) cannot account for the result.

TABLE 2—DEVIATIONS FROM THE LAW OF ONE PRICE FOR RETAIL AND WHOLESALE PRICES

| | Mean absolute (1) | Median absolute (2) | Max absolute (3) |
|------------------------------|----------------------|------------------------|---------------------|
| <i>Panel A. Net prices</i> | | | |
| USA-USA store pairs (31,125) | | | |
| Median | 0.085 | 0.037 | 0.811 |
| Average | 0.087 | 0.042 | 0.858 |
| St. dev. | 0.029 | 0.032 | 0.312 |
| CAN-CAN store pairs (2,775) | | | |
| Median | 0.030 | 0.000 | 0.330 |
| Average | 0.030 | 0.005 | 0.368 |
| St. dev. | 0.020 | 0.012 | 0.159 |
| CAN-USA store pairs (18,450) | | | |
| Median | 0.219 | 0.146 | 1.021 |
| Average | 0.222 | 0.156 | 1.086 |
| St. dev. | 0.033 | 0.041 | 0.303 |
| <i>Panel B. Net costs</i> | | | |
| USA-USA store pairs (31,125) | | | |
| Median | 0.057 | 0.008 | 0.860 |
| Average | 0.058 | 0.018 | 0.892 |
| St. dev. | 0.023 | 0.021 | 0.402 |
| CAN-CAN store pairs (2,775) | | | |
| Median | 0.038 | 0.000 | 1.031 |
| Average | 0.038 | 0.000 | 1.060 |
| St. dev. | 0.011 | 0.001 | 0.397 |
| CAN-USA store pairs (18,450) | | | |
| Median | 0.238 | 0.178 | 1.185 |
| Average | 0.242 | 0.182 | 1.278 |
| St. dev. | 0.039 | 0.046 | 0.194 |

Notes: Panel A refers to net prices and panel B refers to net costs. The table reports within- and between-country statistics (the rows) for the mean absolute, median absolute, and max absolute (log) price gap within store pairs (the columns) for the first week of 2005.

same as the dispersion between US and Canadian city pairs. Broda and Weinstein (2008), using barcode-level data, also find that deviations from the law of one price are similar within and across countries. These authors, however, measure prices for goods with common UPCs purchased from different retailers. In contrast, our data come from the *same* retailer operating in all locations, which is the relevant unit of observation for evaluating pricing to market and deviations from the law of one price.

Panel B indicates similar results for the median absolute marginal cost gap: it is much larger for cross-border store pairs (18 percent) as compared to within-US store pairs (1 percent) and within-Canadian pairs (0 percent).¹⁸ This finding is surprising given that wholesale costs refer to prices of the most tradable component of the retailer's costs.

C. Variance Decomposition of Price Gaps

Prices in our sample change very frequently. The median frequency across UPCs is 0.41 for net prices (0.22 for gross prices), implying a median duration of 2.4

¹⁸The corresponding numbers (not reported) for the median (across store pairs) of the median absolute markup gap (across UPCs) are 6.2 percent within the United States, 1.3 percent within Canada, and 10.5 percent for cross-border pairs.

TABLE 3—VARIANCE DECOMPOSITION OF CROSS-BORDER PRICE GAPS BY PRODUCT

| | | Horizon | | | |
|--------------|--------|---------|---------|-----------|--------|
| | | Weekly | Monthly | Quarterly | Annual |
| Cost share | Median | 0.55 | 0.69 | 0.77 | 0.70 |
| | Mean | 0.63 | 0.62 | 0.66 | 0.57 |
| Markup share | Median | 0.45 | 0.31 | 0.23 | 0.30 |
| | Mean | 0.37 | 0.38 | 0.34 | 0.43 |

Notes: The table decomposes the variance of price gap changes at different horizons into a cost and markup component. The results are based on a rolling window over the 178 weeks in our sample.

(4.5) weeks.¹⁹ Using the decomposition of prices into wholesale costs and markups, we can write the change in the average price gap for product k between the United States and Canada at horizon j as

$$(2) \quad \Delta_j \ln\left(\frac{p^{*k}}{p^k}\right) = \Delta_j \ln\left(\frac{c^{*k}}{c^k}\right) + \Delta_j \ln\left(\frac{\mu^{*k}}{\mu^k}\right),$$

where $\Delta_j x \equiv x - x_{-j}$ is the j -period difference operator, p^k denotes the average price of product k in the United States, p^{*k} is the average price (in US dollars) in Canada, and c^k and μ^k denote, respectively, the average net cost and average markup in the United States (with similar definitions in Canada). Table 3 decomposes the variance of changes in cross-border price gaps (the left-hand side of equation (2)), into a net cost and markup component, across products for various horizons j (one week to one year).²⁰

The table indicates that both wholesale cost gaps and markup gaps contribute to the variability in price gaps. Across products, the median contribution of net costs ranges from 55 percent at the weekly horizon to 77 percent at the quarterly horizon. This indicates that—unconditionally—a substantial fraction of the movements in cross-border prices is accounted for by relative movements in retail markups (between 23 and 45 percent). This fact is consistent with the evidence provided by Eichenbaum, Jaimovich, and Rebelo (2008) using the sample of US stores in our dataset.

III. Prices, Costs and the Nominal Exchange Rate

It is well documented that relative international prices, when measured in a common currency, comove closely with the nominal exchange rate. At the aggregate level, this is simply stating that nominal and real exchange rates are strongly correlated. In this section we first show that this result obtains for the large number

¹⁹We construct the frequency number as follows. We start with the frequency of price adjustment for each UPC-store combination. Next we estimate the average frequency across stores for each UPC. Finally, we report the median (across categories) of the median (within category) frequency.

²⁰Our variance decomposition splits evenly the covariance between relative costs and markups into the cost and markup components. Formally, we estimate the share of costs as $\text{cov}(\Delta_j \ln(c^{*k}/c^k), \Delta_j \ln(p^{*k}/p^k)) / \text{var}(\Delta_j \ln(p^{*k}/p^k))$ with a similar expression for the markup share.

of retail goods in our sample. Next, we show that almost all of the variation in relative retail prices, in response to exchange rate shocks, is explained by variation in relative costs (net or wholesale) and not by variation in relative markups.

A. Median Deviations over Time

First, we relate the variation in relative prices and costs to the nominal exchange rate. We begin by presenting the time variation in the median gap in the average price in US versus Canadian stores located within 200 km of the border. The top-left part of Figure 4 indicates that the median price gap has increased over time, from roughly -5 percent in June 2004 to 15 percent in June 2007. The figure also reports (the dashed line on the right axis) the (log) US/Canadian nominal exchange rate expressed as the US dollar price of the Canadian currency. As is evident, the evolution over time in the median price gap mirrors almost perfectly the evolution of the nominal exchange rate.

The top-right and bottom-left panels perform the same exercise for net costs and the resulting markup. The figure reveals that the movements in the median cross-border cost gap track very closely the movements in the nominal exchange rate. A similar figure obtains when looking at wholesale costs. This finding is surprising since wholesale costs capture the most tradable component of the retailer's total costs (in particular, excluding local labor and nontraded costs). It is clear that the median price gap and median cost gap move closely together, while relative markups show barely any response to the fluctuations in the exchange rate. This suggests that the well-known fact that real exchange rates track the nominal exchange rate is driven largely by the response of wholesale costs to the nominal exchange rate. This result is robust to the definition of the price (gross or net prices) and costs (wholesale or net prices).²¹ Finally, we note that these results differ from the unconditional variance decomposition results presented in Section II, precisely because we are now looking at comovements with the nominal exchange rate.

B. Conditional Variance Decomposition

Next, we explore formally the contribution of cross-border cost movements due to nominal exchange rates to variations in cross-border prices. We start by regressing the j -period change in the cross-border (net) price gap $\Delta_j \ln(p^{*k}/p^k)$ for product k sold in stores located within 200 km of the border on the j -period change in the nominal exchange rate, $\Delta_j \ln S$, where S is the US dollar price of the Canadian currency:

$$(3) \quad \Delta_j \ln(p^{*k}/p^k) = \alpha^k + \beta^k \Delta_j \ln S + \epsilon_j^k.$$

The top panel of Table 4 reports the median, twenty-fifth, and seventy-fifth percentile pass-through coefficient β^k , across products, for various horizons between one week and one year. We find a distribution of pass-throughs narrowly centered on one at all horizons.

²¹ It is also robust to restricting the sample to goods that adjust prices frequently.

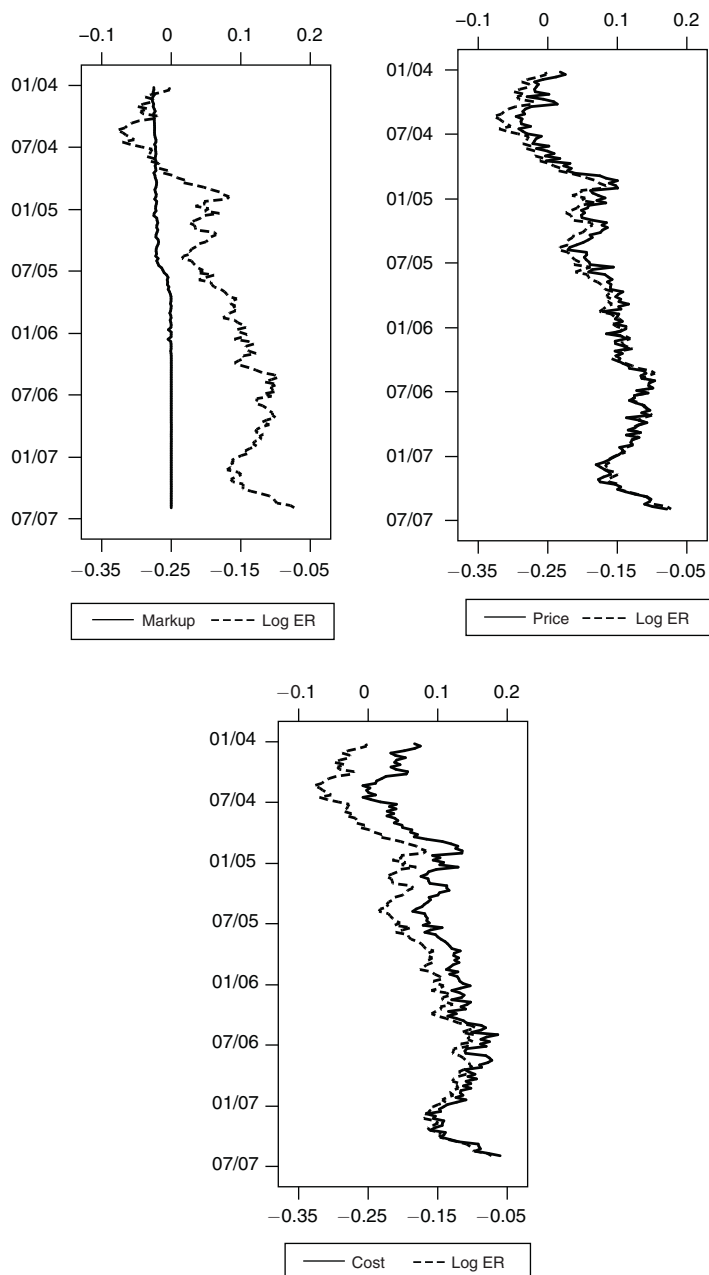


FIGURE 4. MEDIAN NET PRICE, IMPUTED COST, AND MARKUP CROSS-BORDER GAP AND EXCHANGE RATE

The second and third parts of the top panel of Table 4 report the same regression for the net cost and associated markups. The median pass-through coefficient on costs is also very close to one, while the pass-through coefficient on markups is always small and close to zero.²² The results are similar for net and wholesale costs.

²²The coefficients need not sum to one since the median of the average is not the same as the average of the medians.

TABLE 4—EXCHANGE RATE PASS-THROUGH

| | | Horizon | | | |
|---|---------------|---------|-------|---------|-------|
| | | Week | Month | Quarter | Year |
| <i>Panel A. UPC level regression of matched goods</i> | | | | | |
| Price | Median | 1.00 | 1.00 | 1.00 | 1.00 |
| | 25 percentile | 0.86 | 0.84 | 0.91 | 0.88 |
| | 75 percentile | 1.1 | 1.05 | 1.07 | 1.11 |
| Net cost | Median | 1.00 | 1.00 | 1.00 | 1.00 |
| | 25 percentile | 0.97 | 0.98 | 0.97 | 0.93 |
| | 75 percentile | 1.02 | 1.02 | 1.01 | 1.01 |
| Markup | Median | 0.00 | 0.00 | 0.00 | 0.00 |
| | 25 percentile | -0.18 | -0.19 | -0.11 | -0.15 |
| | 75 percentile | 0.2 | 0.1 | 0.14 | 0.2 |
| <i>Panel B. Product group price index regression of all goods</i> | | | | | |
| Price | Median | 0.92 | 0.9 | 0.9 | 1.17 |
| | 25 percentile | 0.51 | 0.6 | 0.51 | 0.12 |
| | 75 percentile | 1.38 | 1.28 | 1.4 | 2.03 |
| Net cost | Median | 0.83 | 0.88 | 0.85 | 1.18 |
| | 25 percentile | 0.45 | 0.52 | 0.41 | -0.17 |
| | 75 percentile | 1.1 | 1.29 | 1.62 | 2.49 |
| <i>Panel C. Product class price index regression of all goods</i> | | | | | |
| Price | Median | 1.01 | 1.03 | 1.01 | 1.15 |
| | 25 percentile | -0.12 | -0.51 | -1.29 | -1.84 |
| | 75 percentile | 2.13 | 2.65 | 3.32 | 3.89 |
| Net cost | Median | 0.91 | 0.93 | 0.99 | 1 |
| | 25 percentile | -0.6 | -1.33 | -2.17 | -2.83 |
| | 75 percentile | 2.23 | 3.9 | 4.11 | 4.65 |

Notes: The table presents summary statistics (across the matched UPCs in our sample) for the pass-through coefficient. In the top panel, we separately estimate a regression of the change in the log Canada-US price, cost, and markup gap on the change in the log Canada-US exchange rate for each UPC. The columns represent the horizon over which we estimate the rolling window regressions. The median, twenty-fifth, and seventy-fifth percentile refer to the distribution of UPCs. The bottom panel uses the change in relative price indexes calculated at the level of product group (61) or product class (1,165).

Taken together, these results confirm that cross-border wholesale costs account for almost all of the pass-through of exchange rates to cross-border prices.

So far we have compared products with the same UPCs. This approach has the virtue of comparing identical products in the two countries and avoids the problem, pointed out by Broda and Weinstein (2008), that aggregation averages out idiosyncratic price shocks and creates an artificial border effect through the volatility of common price shocks (such as the nominal exchange rate). One drawback is that the sample of products with common UPCs is a small subset of all the products available in our dataset. We now expand the sample of products by constructing price indexes at the store level for each product group and product class. There are 61 product groups and 1,165 product classes in the first week of 2004. At these levels of aggregation the match rate across borders is very high: 96 percent for product groups and 70 percent for product classes.²³

Consistent with the exchange rate pass-through regressions presented in Section IIIB, we use all stores within 200km of the border. We calculate separate

²³The Appendix provides additional details about the construction of the price index.

weekly averages of the percentage change in the price index across stores in each country. We then estimate regression (3) on each product group and product class. As our price indexes are calculated in US dollars, the coefficient on the exchange rate is analogous to the one we calculated before for individual products.

The results are reported in the bottom two panels of Table 4. While there is more dispersion in the estimated pass-through coefficient, the median remains close to one at all horizons. This indicates that our results are not driven by special characteristics of the small set of matched goods.

IV. Price Gaps to Market Segmentation

In this section we turn to the second question raised in the introduction: are international markets more segmented than domestic markets? Section II establishes the existence of larger cross-border than within-country price and cost differences. This fact by itself, however, does not tell us that arbitrage costs are larger across borders than within countries. A first step is to establish whether markets are more or less segmented across the US-Canadian border than markets within the United States or Canada. To address this we first present a theoretical discussion of the relevant issues when estimating border costs. We then explain how our findings on the response of relative prices to relative costs shed light on this question. Last, we estimate cost pass-through regressions to determine the extent of relative market segmentation.

A. Theory

The objective is to measure the size of cross-border transaction costs, both in absolute terms and relative to the cost of arbitraging within countries. The border cost, and not price gaps per se, is the object of interest as it is the variable that determines the benefits of market integration and the extent of the transmission of shocks across borders. Here, we present a simple model to guide our empirical approach. Consider a world where markets (indexed by i, j , or k) are distributed across space. Consumer h in market i can pay a price p_i to purchase a homogenous good in market i or can pay a (per unit) transaction cost t_{ij}^h to purchase an identical good at price p_j in market j . Notice that we write this transaction cost as specific to consumer h . Different households in a given market may face different transaction costs depending on their demographic characteristics and preferences. For instance, wealthier households can have a higher opportunity cost of time. Further, we write this transaction cost as the sum of two components: $t_{ij}^h = \tilde{t}_{ij}^h + b$. The first term, \tilde{t}_{ij}^h , represents the transaction cost for household h , were markets i and j to be located in the same country. The second term, b , represents the *additional* transaction costs incurred when markets i and j are located in different countries. This is what we refer to as the “border cost.”

It should be immediately obvious that estimating b is not an easy task. It requires first estimating the total transaction costs between markets i and j , t_{ij}^h , then subtracting what the transaction costs would have been, if markets i and j had been located in the same country, for households with similar characteristics, \tilde{t}_{ij}^h . Both tasks are empirically difficult.

The first task can be accomplished by making additional assumptions on the structure of markets and competition to establish an explicit mapping between the

distribution of prices across markets $\{p_i\}_i$ and the distribution of total transaction costs $\{t_{ij}^h\}_{ijh}$. For example, in the Appendix, we solve for the equilibrium spatial distribution of prices in a modified Steven Salop (1979) model where firms are equally spaced on a circle, and consumers are distributed uniformly and face local transaction costs as well as border costs. In general, the shape of the mapping depends on the specific assumptions of the model. Even without making the strong assumptions necessary to obtain explicit expressions for the equilibrium spatial distribution of prices, however, simple arbitrage arguments can help us characterize the relationship between transaction costs and retail prices, regardless of the specifics of the model. Two cases need to be considered: when markets are integrated, or when they are fully segmented. We describe these two cases and focus on their implications for the effect of transaction costs t_{ij}^h on price gaps.

Integrated Markets.—We define markets i and j as integrated if equilibrium prices in these two markets are such that at least one consumer h in one of the markets is indifferent between buying in the market she lives in or paying t_{ij}^h to buy in the other market. Since this marginal consumer is indifferent between the two markets, the price gap $|p_i - p_j|$ must be equal to the transaction cost t_{ij}^h . It follows that when markets are integrated, observing price gaps is equivalent to observing total transaction costs for at least some households. It does not follow, however, that the comparison of price gaps within and across countries provides an estimate of the border cost, b . To see this, suppose that markets i, j , and k are integrated, with markets i and j located in the same country and market k located across the border. In that case, $|p_i - p_j| = \tilde{t}_{ij}^h$ while $|p_i - p_k| = \tilde{t}_{ik}^l + b$ for some households h and l . Without additional assumptions, b cannot be directly recovered from the observation on price gaps since \tilde{t}_{ik}^l is not observable. An example of one such assumption, often implicitly made in the literature, is that within-country transaction costs are the same regardless of markets: $\tilde{t}_{ij}^h = \tilde{t}_{ik}^l$ for all markets j, k and households h, l . Under this assumption, the border effect can be recovered from the difference between cross-border and within-country price gaps. This is problematic on several grounds. First, transaction costs across markets and countries may differ due to differences in the physical environment as well as household characteristics. Second, it requires that markets are integrated within and across borders, a fact that is often implicitly assumed, and not empirically established.

Segmented Markets.—We define market i and j as segmented when t_{ij}^h is large enough relative to the price gap between the two markets such that all consumers in either market are better off purchasing the good in the market where they live. Consider, again, markets i, j , and k with markets i and j located in the same country and market k across the border. Assume, now, that all three markets are segmented. Then $|p_i - p_j| < \min_h \tilde{t}_{ij}^h$ and $|p_i - p_k| < \min_h \tilde{t}_{ik}^h + b$. When markets are segmented, the price gap is not a function of t_{ij}^h and provides only a lower bound on the distribution of transaction costs. This lower bound is uninformative about the size of t_{ij}^h . Moreover, a comparison of these two lower bounds is uninformative about the size of b even under the additional assumption that $\tilde{t}_{ij}^h = \tilde{t}_{ik}^l$ for all markets j, k and households h, l .

From the previous discussion, it is clear that price gaps alone provide limited information about the degree of market segmentation. To solve this problem, we use information on both prices and costs. The idea is simple. When markets i and j are fully

segmented, an increase in costs in market i , across all products and competitors, c_i , will be passed through to prices in market i , but not to prices in market j , since the latter is shielded from market i .²⁴ It follows that price differences across markets will move closely with cost differences, and markups will not adjust much. On the other hand, when markets are integrated, firms in market i will lose market share if they raise their prices in response to an increase in c_i . In equilibrium, markups will adjust to absorb some of the cost shock. Conversely, firms in market j now face lesser competition from firms in market i and will adjust their markup upward. The pass-through of relative costs into relative prices will be smaller. This is the basic insight of the pricing-to-market literature pioneered by Rudiger Dornbusch (1987) and Paul Krugman (1987).²⁵ In practice, we capture this across-the-board change in costs with exchange rate movements.

To accomplish the second task—estimating b —suppose we can observe the same good sold in stores located at a certain distance and on opposite sides of the border. Now, take the limit as the distance between these stores goes to zero. If market conditions are similar on either side of the border, this implies that the domestic transaction cost term converges to $\tilde{t}_{ii} = 0$. The resulting price gap $|\Delta p|$ directly provides either an estimate of b (when markets are integrated) or a lower bound on b (when markets are segmented). More generally, as long as local transaction costs on both sides of the border become more symmetric as we near the border, the cross-border price gap will provide a lower bound on border cost b .²⁶ This suggests that we look directly at stores located close to the border and motivates the regression discontinuity (RD) approach presented in Section V.

There are three points we take away from this discussion. First, price gaps provide information about the size of transaction cost across markets only when the latter are integrated. The literature on border costs implicitly makes this assumption, which, as we will see, is unwarranted. Second, the key difference between integrated and segmented markets is in the response of price gaps to cost shocks. When markets are integrated, prices in one market respond to changes in costs in the other market; this is not so when markets are segmented. A related implication is that the pass-through of relative costs into relative prices is high when markets are segmented, and low when markets are integrated. Last, one can obtain a direct estimate of (a lower bound of) the border cost b by examining price gaps for stores located close to each other and across the border. These three insights guide our empirical strategy.

We evaluate in two ways whether retail markets are segmented. First, if markets are segmented across borders, then relative prices across stores will move closely with relative costs. For this we need a shock that is plausibly exogenous to relative market conditions for any single product in our sample. Further, they should affect differentially stores located on each side of the border, while being common to all stores within the same country. Fluctuations in the nominal exchange rate are shocks that arguably satisfy these conditions. Our finding in the previous section that, conditional on exchange rate shocks, relative prices comove closely with relative costs is then consistent with retail markets being segmented at the border.

²⁴When markets are segmented, relative prices in market i will not change and consequently markups will not be affected.

²⁵Recent applications of this include Andrew Atkeson and Burstein (2008) and Gopinath, Oleg Itskhoki, and Roberto Rigobon (2010), among others. The Appendix derives this result formally.

²⁶This result is spelled out formally in the Appendix.

Second, we evaluate how prices charged by a given store comove with that store's cost and with the costs of the same product in nearby stores. When markets are segmented, prices charged by a store should be insensitive to cost shocks to a neighboring store, conditioning on their own cost. When markets are integrated, prices will comove with these cost changes even after conditioning on the store's own cost. We explore this in the next subsection.

B. Cost-Price Pass-Through

To compare the extent of retail market segmentation within and across countries, we estimate cost pass-through regressions. These regressions allow retail prices in one region to depend on costs in the same location, as well as costs in neighboring regions. As our theoretical discussion indicates, under segmentation, local product prices should not depend on cost and market conditions in other markets. By contrast, when markets are integrated, local product prices should vary with cost and market conditions in other markets.

We implement these regressions for our sample of matched products in the following way. First, we compute the average price and cost for each product across Washington State stores located within 200km of the US-Canada border (near US). We compute the same averages in the next 200km band within the US (far US). These stores are located in Washington and Oregon. We replicate the exercise on the Canadian side of the border with stores within 200km of the border in British Columbia (near Canada) and Alberta (far Canada). We then regress for each product the j -period change in price in region i , $\Delta_j \ln p_i^k$, on the j -period change of its own cost $\Delta_j \ln c_i^k$ and the j -period change of costs in adjacent regions l , $\Delta_j \ln c_l^k$, located on the same side or on opposite side of the border:

$$(4) \quad \Delta_j \ln p_i^k = \alpha \Delta_j \ln c_i^k + \beta \Delta_j \ln c_l^k + \epsilon^k.$$

Table 5 reports the results. Across all goods and locations, the median pass-through from own costs to prices is positive and large, ranging between 0.24 and 0.52. The cost pass-through from neighboring regions is smaller but still sizeable within countries, especially at shorter horizons. It ranges from 0.12 in the United States to 0.15 in Canada for weekly price changes. This indicates significant comovements between prices in one region and costs in an adjacent region within each country. By contrast, the cross-border cost pass-through reported in the middle panel is always zero, regardless of the horizon.

While these regression coefficients should be interpreted simply as establishing some degree of comovement between costs and prices, and not as the causal impact of changes in costs on prices (unlike the case of the exchange rate shock), they nevertheless confirm our earlier diagnostic that domestic retail markets exhibit less segmentation than cross-border markets.

Overall, our results strongly suggests that the US-Canada border almost perfectly segments the retail and wholesale markets that we examine, while within-country retail markets appear partially integrated.²⁷

²⁷The evidence that some consumers cross the border to arbitrage price differences (e.g., Jeffrey R. Campbell and Beverly Lapham 2004) is not inconsistent with our claims. Our results simply indicate that the price-setting

TABLE 5—COST PASS-THROUGH

| | | Percentile | Horizon | | | |
|----------|--------------|------------|---------|-------|---------|-------|
| | | | Week | Month | Quarter | Year |
| Far US | Own cost | Median | 0.35 | 0.37 | 0.47 | 0.45 |
| | | 25th | 0.05 | 0.05 | 0.1 | 0.16 |
| | | 75th | 0.74 | 0.79 | 0.89 | 0.85 |
| | Near US cost | Median | 0.12 | 0.14 | 0.05 | 0.05 |
| | | 25th | 0 | -0.01 | -0.04 | -0.05 |
| | | 75th | 0.38 | 0.52 | 0.25 | 0.19 |
| Near CAN | Own cost | Median | 0.46 | 0.5 | 0.52 | 0.44 |
| | | 25th | 0.22 | 0.24 | 0.26 | 0.22 |
| | | 75th | 0.85 | 0.92 | 0.97 | 0.94 |
| | Near US cost | Median | 0 | 0 | 0 | 0 |
| | | 25th | -0.05 | -0.06 | -0.06 | -0.08 |
| | | 75th | 0.06 | 0.08 | 0.09 | 0.08 |
| Near CAN | Own cost | Median | 0.26 | 0.24 | 0.24 | 0.24 |
| | | 25th | 0.08 | 0.05 | 0.06 | 0.05 |
| | | 75th | 0.53 | 0.56 | 0.54 | 0.55 |
| | Far CAN cost | Median | 0.15 | 0.16 | 0.21 | 0.17 |
| | | 25th | 0.02 | 0.01 | 0.02 | 0 |
| | | 75th | 0.41 | 0.42 | 0.49 | 0.42 |

Notes: The table presents summary statistics (across the matched UPCs in our sample) for the pass-through coefficient. For each UPC we separately estimate the pass-through from the change in log own costs and log of neighbor's costs into the change in log of own prices. The prices and costs are calculated as weekly averages for the stores in the regions we consider: near US (WA stores within 200km of the border), far US (WA and OR stores 200–400km from the border), near CAN (BC within 200km of the border), and far CAN (Alberta within 200km of the border). We do this for rolling windows over horizons from one week to one year. The median, twenty-fifth, and seventy-fifth percentile refer to the distribution of UPCs.

V. A Regression Discontinuity Estimate of the Border Effect

The previous section establishes that markets are segmented across countries. It follows that cross-border price gaps provide a lower bound on *total* cross-border transaction costs t_{ij}^h . This section proposes the use of the regression discontinuity (RD) design, following the discussion in Section IVA, to estimate directly a lower bound on the border cost b .²⁸

The RD approach allows us to answer the following question: by how much do prices of goods sold in stores located immediately across the border differ?²⁹ The motivation for the RD approach is twofold. First, equilibrium prices depend on many local factors, such as the elasticity of substitution across stores, or demographic characteristics, all of which have an impact on the effective transaction costs for a household and can vary with location. The RD approach controls for all these determinants. Second, by explicitly controlling for distance, we approximate more closely the component of the transaction costs directly associated with the border.

decision by stores in our sample is not significantly affected by these consumers.

²⁸See Guido W. Imbens and Thomas Lemieux (2008) for a practical guide to the RD framework. See also the February 2008 special issue of the *Journal of Econometrics*.

²⁹Thomas Holmes (1998) uses a similar approach to estimate the effect of right-to-work laws on employment across US states.

We describe the details of the RD methodology in the Appendix. Formally, we follow Imbens and Lemieux (2008) and use a local linear regression approach including distance to the border as a regressor, interacted with a border dummy:

$$(5) \quad \ln p_i^k = \alpha^k + \gamma^k C_i + \theta^k D_i + \delta^k C_i \cdot D_i + \beta^k X_i + \epsilon_i^k.$$

As before, p_i^k denotes the US dollar price of good k sold in location i , C_i is a border dummy equal to one if the store is located in Canada and zero otherwise, D_i denotes the algebraic distance of store i to the border in km (positive for US stores and negative for Canadian ones), and X_i measures other important observable characteristics of market i . Finally, ϵ_i^k captures unobserved characteristics that are store- and good-specific. The parameter of interest is γ^k . It estimates (a lower bound on) the border effect for good k , expressed as a percent of the price of that good.³⁰

Graphically, Figure 1 illustrates how the regression discontinuity approach can recover an estimate of the border effect. The figure plots the (log) average price across stores (in 50-kilometer bins) for 25-ounce bottles of Perrier Sparkling Natural Mineral Water against the individual store's distance from the border. As is evident, there is a clear price discontinuity at the border that is indicative of the treatment of the border. The RD design controls for the fact that stores located far apart can face very different market conditions or arbitrage costs compared to stores located close to one another. The discontinuity at the border is interpreted as a lower bound (since markets are segmented) on the pure effect of the border.

As discussed earlier, the covariates X_i capture important demand characteristics that might vary with location.³¹ We include population density, density of supermarkets and other grocery stores, the proportion of people age 0–19 years and age 65 years and over, the proportion of black people, the year the store was opened, and household income in year 2000 expressed in US dollars. All these variables are described in the Appendix. Summary statistics are presented in panel B of Table 1.

The key assumption of the RD approach is that the unobserved characteristics ϵ_i^k do not change discontinuously at the border. Although we cannot test this assumption directly, we do two things to assess its plausibility. First, we examine the distribution of stores' distances to the border to see whether a store's location is discontinuous at the border. A discontinuity would suggest that the store's location is endogenous to the treatment, potentially invalidating our design. Second, we examine whether the observable market characteristics X_i also change discontinuously at the border. If the observable characteristics do not change discontinuously at the border, then one may be more confident that this is also the case for the unobservable characteristics.³² In the same spirit, we compare estimates of γ^k with and without controls for observable characteristics.

³⁰The local linear regression also restricts the sample to stores within a distance \bar{D}_k from the border. In practice, we set \bar{D}_k to 500km. Imbens and Lemieux (2008) recommend choosing \bar{D}_k using a standard cross-validation procedure. For most products, the optimal bandwidth is either 100, 350, or 500km. Results are unchanged if we adopt the optimal bandwidth.

³¹Holmes (2008) considers similar variables when estimating the demand for products sold in Walmart stores.

³²Moreover, even if observable characteristics are not continuous at the border, this does not invalidate our design, as long as the effect of the covariates X_i on the dependent variable remains the same on each side of the border and we control for these characteristics.

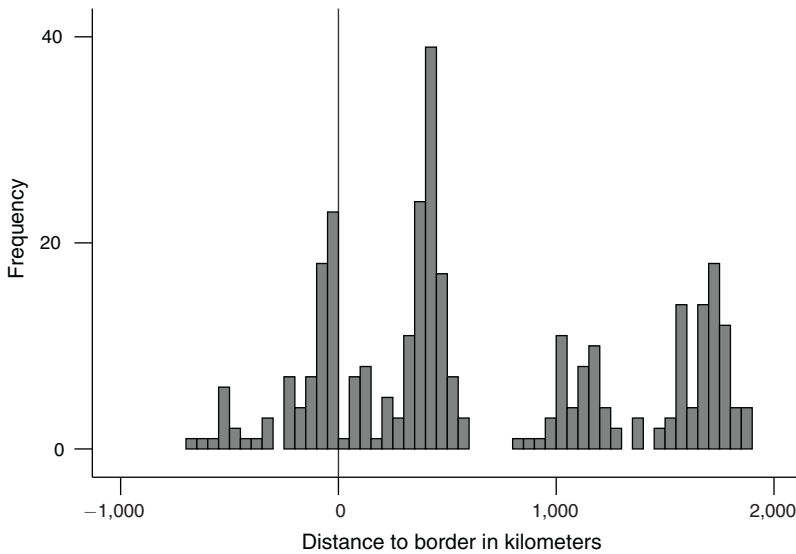


FIGURE 5. DISTANCE TO THE BORDER

Note: Distance to the border is positive for US stores, negative for Canadian stores.

A. Graphical Analysis

We begin by plotting the distribution of each store's distance to the US-Canadian border (in kilometers).³³ Figure 5 plots the density of all stores of the retail chain as a function of the algebraic distance to the border (that is, distance is negative for Canadian stores and positive for US stores). Each bin width is 50 kilometers.

As can be seen, all Canadian stores are located less than 1,000 kilometers from the border, while many stores in the United States are more than 1,000 kilometers from the border. Obviously, the geographic concentration of economic activity in the United States is very different from that in Canada, highlighting Gorodnichenko and Tesar's (2009) caution about estimates that do not take within-country heterogeneity differences into account. Nonetheless, we do not observe any significant discontinuity in store density at the border. This suggests that, for this retailer, the location of stores does not appear to be directly influenced by proximity to the border. From Figure 2, it is also apparent that many Canadian stores close to the border have no counterpart on the US side. This is especially true for Canadian stores in eastern British Columbia and Alberta. To address this issue, we also present results with a sample of stores located in Oregon and Washington on the US side, and British Columbia in Canada (21 Canadian and 41 US stores) where there is an important concentration of stores close to the border and where market conditions are also likely to be more homogenous. We refer to this group of 62 stores as the "West Coast sample."

Figure 6 depicts graphically the regression discontinuity for the market characteristics included in X_i . Each point is the average value of the relevant variable within

³³The distance was calculated using the ArcGIS software.

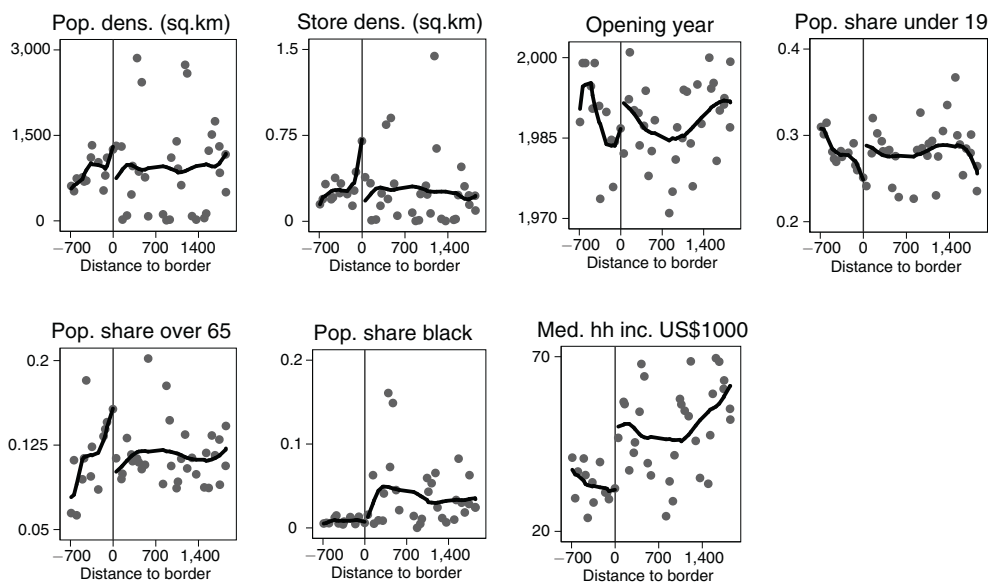


FIGURE 6. REGRESSION DISCONTINUITY FOR COVARIATES

Note: Store distance to the border is positive for the United States, negative for Canada.

50-kilometer bins. For several of these variables, no stark graphical discontinuity is apparent. We formally test for this result and find that there is some discontinuity at the border for the age variables, for the proportion of blacks and for median household income. When we restrict attention to the West Coast subsample of stores, some discontinuities disappear, but we find discontinuities for the fraction of senior citizens as well as for median household income. Further, when we consider all ZIP codes and census subdivisions in Canada and the United States, not just the ones for which we have store data, we cannot find any evidence of discontinuities for any of our covariates. We conclude from this graphical analysis that our RD design is valid, since we can find no clear evidence that market conditions or store locations are systematically affected by the border.

B. Regression Discontinuity Estimates

Panels A through F of Figure 7 plot the kernel density of point estimates obtained by estimating regression (5) by UPC for the first week of 2004 and the twenty-first week of 2007. For our main specification, we use all stores within 500 kilometers of the border.³⁴ We do this estimation separately for the retail price, net cost, and markup, for each UPC and for each week, both with and without controls for the covariates. Panels A–F illustrate that the border effect on prices varies substantially

³⁴We also restrict the sample to those UPCs that have a minimum of ten store observations on both sides of the border.

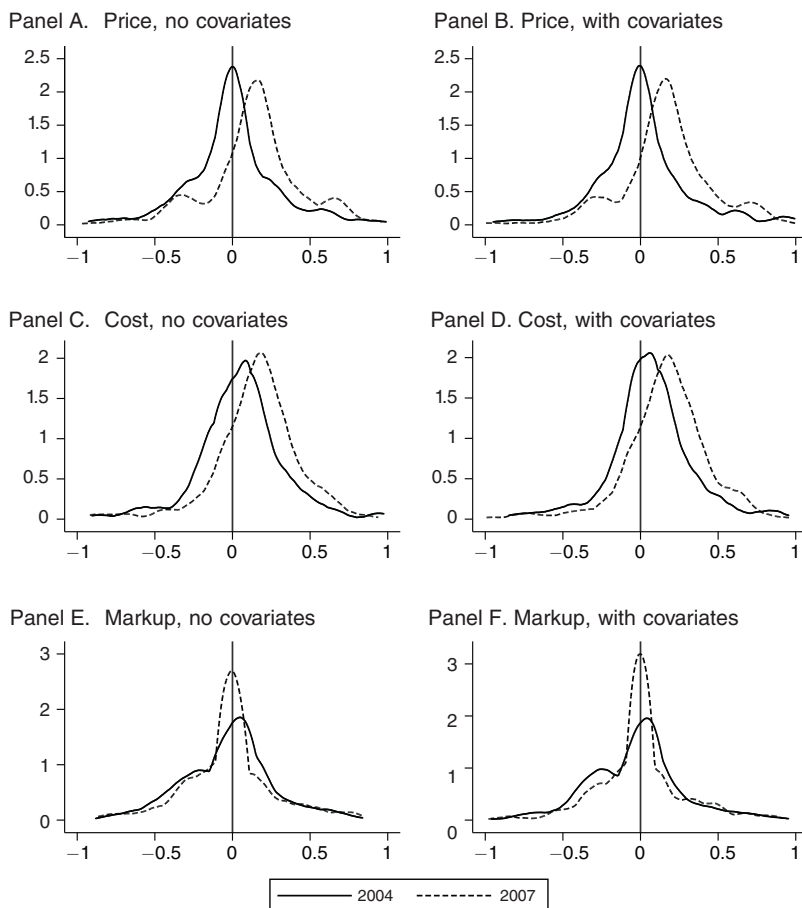


FIGURE 7. DISTRIBUTION OF REGRESSION DISCONTINUITY ESTIMATES OF PRICE, COST, AND MARKUP GAPS

Note: 2004 refers to the first week of 2004; 2007 refers to the twenty-first week of 2007.

across products.³⁵ As can be seen, the border discontinuity in prices is centered around zero in the first week of 2004, but shifts significantly to the right by 2007. The distribution of the border discontinuity in costs also shifts to the right from 2004 to 2007. Thus, it appears that the depreciation of the US dollar over this period increased both the costs and prices in Canadian stores close to the border relative to US stores on the other side of the border. As for the markups, the border effect on markups shifted slightly to the left from 2004 through 2007, suggesting that the depreciation of the US dollar lowered markups in Canadian stores relative to the markups in US stores. A visual inspection of the shift in the distribution of costs and markups suggests, however, that the shift in marginal costs overwhelms the change in retail markups.

³⁵This finding is consistent with the fact that stores in our sample may not choose their location as a function of the border, since for many products, the price gap is positive, but for many others it is negative.

TABLE 6—REGRESSION DISCONTINUITY ESTIMATES

| | Median | Mean | SD | Frac. sign. | Median abs. | Mean abs. | No. of UPCs |
|--|--------|-------|------|-------------|-------------|-----------|-------------|
| <i>Panel A. All stores</i> | | | | | | | |
| Price | 0.15 | 0.13 | 0.37 | 0.70 | 0.21 | 0.28 | 481 |
| Cost | 0.17 | 0.15 | 0.31 | 0.80 | 0.21 | 0.26 | 481 |
| Markup | 0 | -0.02 | 0.37 | 0.40 | 0.14 | 0.23 | 481 |
| <i>Panel B. West Coast stores</i> | | | | | | | |
| Price | 0.22 | 0.26 | 0.32 | 0.86 | 0.24 | 0.33 | 212 |
| Cost | 0.22 | 0.20 | 0.27 | 0.83 | 0.24 | 0.27 | 212 |
| Markup | 0 | 0.06 | 0.36 | 0.44 | 0.13 | 0.23 | 212 |
| <i>Panel C. Washington-Oregon stores</i> | | | | | | | |
| Price | 0 | 0.01 | 0.09 | 0.24 | 0.01 | 0.04 | 370 |
| Cost | 0 | 0 | 0.06 | 0.17 | 0 | 0.02 | 370 |
| Markup | 0 | 0 | 0.10 | 0.22 | 0.02 | 0.04 | 370 |

Note: Distribution for week 21 of 2007.

The covariates do have some explanatory power for price gaps across stores, both within and across countries. We calculate the adjusted R^2 from a regression of store prices on our store-level covariates for each UPC in the first month of 2004 and compute the mean and median across UPCs.³⁶ The adjusted R^2 for prices is in the 10–15 percent range while the adjusted R^2 for costs varies between 8 and 12 percent. This is consistent with our retailer making pricing decisions at a more granular level than the wholesale market—stores that purchase from the same wholesaler at the same cost may nevertheless charge different prices due to different local demand conditions. As for the coefficient on covariates, these are often quite small, as the estimates at the UPC level are quite noisy and dispersed across UPCs. Overall, we find that prices are higher in areas that have higher median incomes, lower population densities, greater competition, fewer senior citizens, and older stores.³⁷

Importantly, even though store-level covariates explain a significant share of price differences across stores, they have little effect on our estimated border coefficient. The distributions reported in panels A–F of Figure 7 look very similar when the regression is estimated without (left panel) and with (right panel) covariates. This comparison assuages concerns that an omitted variable might result in biased estimates of the border effect.

Table 6 reports summary statistics for the distribution of prices, costs, and markups for week 21 of year 2007 (without covariates) plotted in panels A–F of Figure 7. The median price (net cost) treatment effect is 15 percent (17 percent) for the full sample. When restricted to the West Coast subsample (panel B) the estimates are 22 percent (22 percent). We find no evidence of a border treatment for markups in either sample. Across all weeks, the median absolute price treatment effect varies between 19.6 and 24.2 percent. Recalling that the estimated border effect in week

³⁶These adjusted R^2 are obtained by pooling stores in both countries and partialling out the effect of the border on prices and covariates so that the coefficient estimates are similar to those obtained in our regression discontinuity estimates.

³⁷These results can be requested from the authors. We also performed the same regressions using store-level price indexes, relative to a base store. This results in significantly bigger coefficient estimates, as idiosyncratic price differences are averaged out. The signs on the coefficients are similar, however.

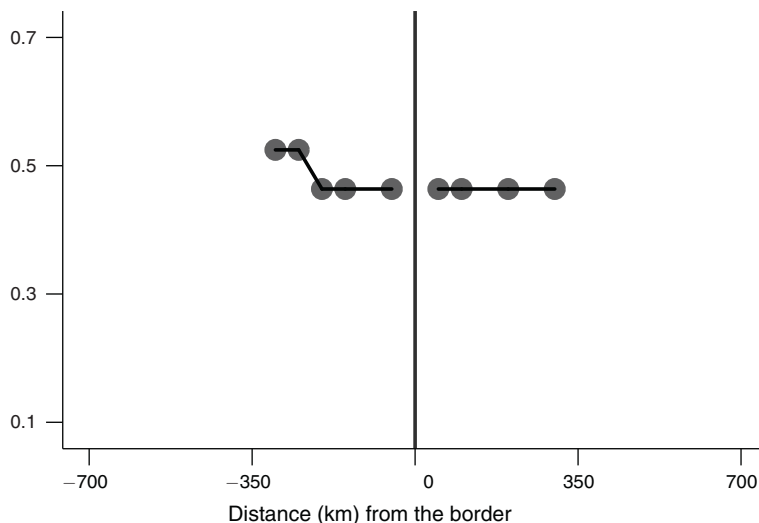


FIGURE 8. GRAPHICAL DEPICTION OF WASHINGTON-OREGON BORDER REGRESSION DISCONTINUITY FOR PERRIER SPARKLING NATURAL MINERAL WATER

Notes: Perrier Sparkling Natural Mineral Water, 25-ounce bottles. Store distance to the border is positive for Oregon, negative for Washington.

t for product k , $\hat{\gamma}_t^k$, is a lower bound on the true border effect γ^k when markets are segmented, it follows that the true border effect at the retail level is at least as high as 24 percent.³⁸ Similarly, the median absolute treatment effect for net costs varies between 19.9 and 24.8 percent.³⁹

As in Section III, we want to compare our evidence on cross-border price, cost, and markup border treatments to within-country estimates. We do so by estimating the treatment of the Washington-Oregon border on our West Coast subsample for the set of matched products.⁴⁰ This serves an important purpose: within-country border discontinuities provide a natural benchmark for cross-border discontinuities. In the language of the treatment effect literature, the Washington-Oregon border serves as a placebo. To illustrate, Figure 8 is similar to Figure 1 for the Washington-Oregon border. It is immediate that—at least for 25-ounce bottles of Perrier Sparkling Natural Mineral Water—there is no price discontinuity at the state border. This finding is confirmed for our broader set of goods: panel C of Table 6 finds no evidence of a discontinuity in prices or costs. This is in spite of the fact that some Washington stores are in a different pricing area, as is evident in Figure 8. State borders may sometimes form a natural pricing area when they coincide with large differences in competition and demographics, but many pricing areas seem to straddle multiple states or provinces in our sample. This underscores the importance of our RD design—if we simply compared average prices across Washington and Oregon, we might conclude that the state border segments markets and has a big impact. By

³⁸Formally, if $\hat{\gamma}_t \leq \gamma$, then $\max \hat{\gamma}_t \leq \gamma$.

³⁹All these results hold similarly for the West Coast subsample.

⁴⁰Similar results are obtained when the sample is extended to include all UPCs traded within US boundaries.

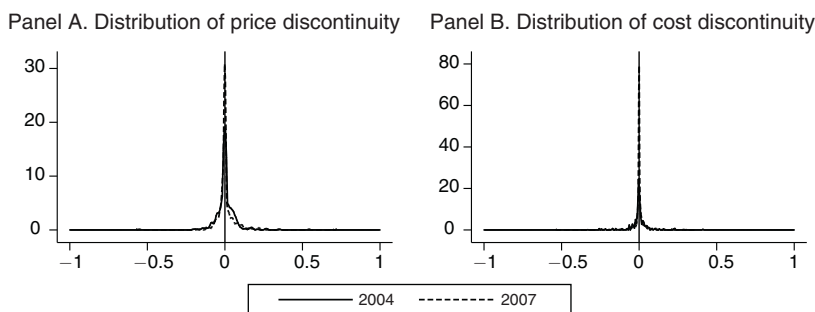


FIGURE 9. INTRANATIONAL BORDERS REGRESSION DISCONTINUITY: THE WASHINGTON-OREGON BORDER

Note: 2004 refers to the first week of 2004 and 2007 refers to the twenty-first week of 2007.

focusing on the stores closer to the border and including distance as a regressor, we correctly ascertain that these stores share similar local environments and estimate a zero impact of the state border.

Panels A and B of Figure 9 plot the distribution of treatment effects by UPC at the Washington-Oregon border for prices and net costs. We find that, in contrast to the panels in Figure 7, the point estimates are almost all concentrated at zero for both weeks we consider.

VI. Discussion

The previous results establish pricing to market at the wholesale cost level. As we have emphasized, this is the more novel aspect of our findings. In this section, we discuss some potential explanations for our findings. Since we have only limited information on the price-setting process at the wholesale level, our discussion is necessarily speculative.

Our starting point is that, as for retail prices, international differences in wholesale costs require factors that cause wholesale costs to differ across markets, as well as significant costs to international arbitrage. What are these transaction costs? From a consumer's perspective, fairly small transaction costs can effectively segment retail markets. By contrast, given the large volumes involved at the wholesale level, the gains to arbitraging even small price gaps are potentially large.

One possibility arises from the structure of the distribution network. Our retailer operates 13 distribution centers in the United States and 4 in Canada. All stores are attached to a distribution center that provides the majority of the products to individual stores. Typically, wholesalers and manufacturers send goods to a distribution center, which then dispatches the goods to local stores. A US store close to the border receives its products from a US distribution center. That distribution center, however, may be located far away from the border. Similarly, a Canadian store close to the border receives its products from a Canadian distribution center. That distribution center may, too, be located far away from the border. In that case, the stores' proximity to the border would be irrelevant for wholesale cost gaps. What would matter is the distance of the distribution centers from each other and the ability of the retailer to ship goods across distribution centers. To investigate this possibility, we

collected information on the physical location of the distribution centers.⁴¹ We found that several distribution centers across the border are located close to one another, especially in British Columbia and Washington state. For instance, the Vancouver and Seattle distribution centers are located only about 130 miles from each other. We conclude that the distance between distribution centers is not a primary source of wholesale market segmentation.⁴²

A more promising possibility is that corporate agreements specifically prohibit retail stores from arbitraging prices across borders. That is, Canadian retail stores have to buy from Canadian distributors while US retail stores have to buy from US distributors. More generally, the border may facilitate a segmentation of the supply chain at the wholesale level. To answer this question, we consider products that are sold under the brand of the retail chain that we call “store brands.” Because the retail chain arguably controls a larger segment of the supply chain for these store brands, we would expect the wholesale market segmentation to be less severe.⁴³ To explore this possibility, we regress the mean (across all weeks) log absolute maximum cost gap and standard deviation on a constant and a dummy for store brands.⁴⁴ Within countries, our variable measures the maximum cost gap and standard deviation across operating areas.⁴⁵ Across countries our variable measures the gap between the average cost (across operating areas) of each country. The results are presented in Table 7. The evidence suggests that, in general, the log absolute cost gaps and standard deviations are lower in the case of the store brands than for other goods. Except within Canada, both the maximum cost gap and its standard deviation are lower for store brands. This is consistent with the view that suppliers are less able to segment wholesale markets when they exert less control over the supply chain.

We do not have detailed information on whether and how wholesale contracts differ for store brands, but this evidence suggests that pricing to market at the wholesale level is less prevalent among store brands. To the extent that the store brands are also largely sourced from independent producers, it is, however, not surprising that they do not behave dramatically differently from other goods.

Finally, there is the question of why wholesale prices are different, even if buyers cannot arbitrage the markets. This is perhaps the most surprising aspect of our results: why would the prices in these two very similar countries be so different for identical products? One possibility is that our retailer sources from different suppliers in the US and Canada. Wholesale costs may vary across countries to the extent that wholesaler’s marginal costs include a local cost component. If these local prices (set in local currency) do not respond to nominal exchange rates, this would generate our findings regarding wholesale prices.⁴⁶ We learned that several of the matched

⁴¹ A map of the distribution centers is available online on the corresponding author’s Web page.

⁴² Recall, too, that our results are robust when we consider exclusively West Coast stores.

⁴³ Our retailer reports that approximately 23 percent of store brands are manufactured in company-owned plants.

⁴⁴ We exclude the category “books and magazines” from the sample since there are no store brands in that category.

⁴⁵ There are nine operating areas in the United States and four in Canada.

⁴⁶ A well-known example is Coca-Cola. The Coca-Cola company produces syrup in the United States which is then sold to licensed bottlers in different countries. The bottlers, who hold exclusive rights over a particular country/area, manufacture the finished product by adding filtered water and sweeteners, then distribute it. The marginal cost of the retail bottle of Coke contains a substantial local currency component. If this component does not respond to nominal exchange rate movements, fluctuations in relative wholesale prices will result. Gopinath and Rigobon

TABLE 7—RETAILER BRANDS

| Dependent variable | Log absolute gap | Standard deviation |
|----------------------|----------------------|----------------------|
| <i>Canada</i> | | |
| Retailer brand | 0.002 (0.002) | -0.024** (0.011) |
| Constant | 0.005*** (0.001) | 0.032*** (0.004) |
| <i>United States</i> | | |
| Retailer brand | -0.032*** (0.011) | -0.281*** (0.060) |
| Constant | 0.082*** (0.003) | 0.320*** (0.018) |
| <i>Cross-border</i> | | |
| Retailer brand | -0.032*** (0.011) | |
| Constant | 0.130*** (0.003) | |

Notes: Standard errors in parentheses. Dependent variables are mean (across all weeks) log absolute cost gap and standard deviation. Within countries this is the maximum cost gap across operating areas and the standard deviation across operating areas (nine in the United States, four in Canada). Across countries this is the gap between the average cost (across operating areas) of each country.

goods in our sample list the United States as the country of origin. This may not suffice, however, to identify the “source,” as a good may have to go through different wholesalers/distributors in different countries. In addition, Canadian goods may have to go through an extra step to comply with the labeling language requirements in that country. Recent evidence presented by Doireann Fitzgerald and Stefanie Haller (2008) and Burstein and Jaimovich (2008) seem to confirm that wholesale prices can vary significantly across destination, even for goods manufactured in the same plant (same country). This burgeoning literature suggests that wholesale pricing to market is not fully explained by differences in production costs across locations. Nevertheless, more information on the supply chain and the role of local distributors can renew the importance of different local costs in explaining the comovement of relative wholesale prices and the exchange rate.

A fruitful area of future research will be to explore in more detail, and more systematically, the source of these wholesale-level price differences. This will require gathering detailed information on the structure of the supply chain, manufacturing, and distribution costs at different nodes in the chain. Our contribution has been to establish the widespread nature of pricing to market at the wholesale level. Of course, a limitation of our work is that we examine a specific set of goods sold by a single grocery chain. To the extent that the nature of price setting and the costs of arbitrage vary across goods or across retailers, further work that encompasses a wider range of goods and retailers would also be very useful.

(2008) and Gopinath, Itskhoki, and Rigobon (2010) provide evidence of contracts with fixed at-the-dock dollar prices for US imports. These dollar prices do not respond fully to the exchange rate.

APPENDIX

Regression Discontinuity Methodology

Consider the following empirical model of the relationship between the US dollar price p_i^k of product k in store i and various covariates:

$$(6) \quad \ln p_i^k = \alpha^k + \gamma^k C_i + \beta^k X_i + \epsilon_i^k,$$

where C_i is a dummy variable that is equal to one if store i is located in Canada, X_i measures other observable characteristics of market i , and ϵ_i^k captures unobserved characteristics that are store- and good-specific. The parameter of interest is γ^k . The inference problem is that the unobserved characteristics may not be independent from the location of store i , that is, $E[\tilde{\epsilon}_i^k | C_i] \neq 0$, which can bias simple border regression estimates.

If, however, the unobserved characteristics are a continuous function of the distance between stores and the border, we can control for these characteristics by introducing distance from the border as an additional regressor. Define D_i as the distance (in kilometers) from store i to the border. By convention, stores located in the United States are at a positive distance from the border ($D_i > 0$), while stores located in Canada are at a negative distance ($D_i < 0$). With this convention, a store exactly on the border would have $D_i = 0$. The key identifying assumption, then, is that the unobserved characteristics do not change discontinuously at the border:

$$\lim_{\varepsilon \uparrow 0} E[\tilde{\epsilon}_i^k | D_i = \varepsilon] = \lim_{\varepsilon \downarrow 0} E[\tilde{\epsilon}_i^k | D_i = \varepsilon].$$

The effect of the border can then be estimated as

$$\gamma^k = \lim_{\varepsilon \uparrow 0} E[\ln p_i^k - \beta^k X_i | D_i = \varepsilon] - \lim_{\varepsilon \downarrow 0} E[\ln p_i^k - \beta^k X_i | D_i = \varepsilon].$$

In this expression, γ^k answers the question: how do prices change when one crosses from $D_i = \varepsilon$ to $D_i = -\varepsilon$, where ε is some small number?

We follow Imbens and Lemieux (2008) and estimate γ^k using a local linear regression approach including distance as an additional regressor, interacted with the border dummy:

$$(7) \quad \ln p_i^k = \alpha^k + \gamma^k C_i + \theta^k D_i + \delta^k C_i \cdot D_i + \beta^k X_i + \epsilon_i^k.$$

Importantly, this local linear regression restricts the sample to stores within a distance of \bar{D}_k from the border, that is, $|D_i| < \bar{D}_k$. The optimal distance \bar{D}_k can be selected using a standard bandwidth selection criterion based on the cross-validation

procedure advocated by Imbens and Lemieux (2008).⁴⁷ The optimal bandwidth ranges from 100 to 700 kilometers. For most weekly product-group pairs, the optimal bandwidth is either 100, 350, or 500 kilometers. All store-level observations beyond this cutoff are effectively discarded. In practice, we choose a bandwidth of 500km.

Circular World

We present a model that endogenizes the distribution of prices across locations in the presence of border costs. The model is a two-country version of Salop's (1979) circular city model of horizontal differentiation. We define a location as a position indexed by $\omega \in [0, 1]$ on a circle of unit circumference. A border splits the circle into two countries (country *A* and country *B*). The details regarding the derivation of results are available from the authors upon request.

Stores

There are $N_{AB} = N_A + N_B$ retail stores located at exogenous equidistant intervals along the circle, with N_A stores in country *A* and N_B stores in country *B*. The borders are located at $\omega = 0$ and $\omega = N_A/N_{AB}$. We refer to stores by their location, parameterized by the variable ω_i , where $i \in \{1, \dots, N_{AB}\}$, with $\omega_i = (2i - 1)/2N_{AB}$. The stores closest to the border are $i = 1, N_A$ for country *A*, and $i = N_A + 1, N_{AB}$ for country *B*. We further assume that each store sells a homogenous good (same UPC) and sets the price of this good independently.⁴⁸

Consumers

We assume that a unit mass of consumers is uniformly distributed on the unit circle. Each consumer buys one unit of the good and, all else equal, strictly prefers to shop in stores that are located close to them. They incur a cost $t \geq 0$ per unit of distance traveled that reflects transportation costs or the individual consumer's value of time, as well as a cost $b \geq 0$ when crossing the border. The utility of a consumer located at ω and shopping in store i is given by

$$u(\omega) = \nu - \theta p - t|\omega_i - \omega| + bI(\omega_i, \omega).$$

Here, $I(\omega_i, \omega)$ is an indicator function for whether the consumer and store are located in different countries, θ captures the own price elasticity of demand, and t is inversely

⁴⁷The procedure looks for the minimum value of the cross-validation criterion in 100-kilometer increments.

⁴⁸This assumption may seem at odds with our data, which consist of stores operated by a single retail chain. Yet this is a reasonable assumption that captures the notion that pricing decisions in any given location are more influenced by the pricing decisions of competitors located in the immediate vicinity than by the pricing decisions of stores belonging to the same chain located farther apart. In our model, if we assume that the particular retail chain we have data from operates every other store along the circle, then each store in the chain behaves exactly like an independent store.

related to the degree of substitutability across store locations. We assume that ν is large enough so that in equilibrium all consumers purchase one unit of the good.

Costs

The marginal cost of goods in location i is

$$c_i = \begin{cases} \min\{\chi_A, \chi_B + b_c\}, & \text{if } i \in A \\ \min\{\chi_B, \chi_A + b_c\}, & \text{if } i \in B. \end{cases}$$

Here, χ_j denotes the wholesale price of the good in country j , and $b_c \geq 0$ is the border cost incurred by the retailer. Note that it will always be the case that c_i is the same for all stores in the same region.

We solve for the equilibrium distribution of prices in the following manner. We first solve for the profit-maximizing price for interior stores, defined as stores not adjacent to the border. We then consider the profit-maximizing prices of the border stores. If we assume that the parameters of the model are such that all stores earn positive profits in equilibrium, this implies that consumers will not shop at stores that are farther than $1/N_{AB}$ from their own location. Between any pair of stores i and $i - 1$, there will be a marginal consumer indifferent between shopping at either store.

Interior Stores.—Consider an interior store i in country j . That store chooses its price p_i to maximize static profits. The following proposition characterizes the distribution of interior prices.

PROPOSITION 1: *The distribution of interior prices takes the following form:*

(i) For stores in the interior of country A:

$$(8) \quad p_i = \left(\hat{p}_A - c_A - \frac{t}{N_{AB}} \right) \cdot \frac{\cosh\left(\kappa\left(i - \frac{N_A + 1}{2}\right)\right)}{\cosh\left(\kappa\left(\frac{N_A - 1}{2}\right)\right)} + c_A + \frac{t}{N_{AB}};$$

(ii) For stores in the interior of country B:

$$(9) \quad p_i = \left(\hat{p}_B - c_B - \frac{t}{N_{AB}} \right) \cdot \frac{\cosh\left(\kappa\left(i - N_A - \frac{N_B + 1}{2}\right)\right)}{\cosh\left(\kappa\left(\frac{N_B - 1}{2}\right)\right)} + c_B + \frac{t}{N_{AB}}.$$

In the expressions above, \cosh denotes the hyperbolic cosine function, $\kappa \equiv \cosh^{-1}2 \approx 1.317$ is a constant, $\hat{p}_A = p_1 = p_{N_A}$ represents the price in the border store in country A, and $\hat{p}_B = p_{N_{AB}} = p_{N_A+1}$ represents the price in the border store in country B.⁴⁹

⁴⁹The hyperbolic cosine function is given by $\cosh(x) = (e^x + e^{-x})/2$.

As equations (8) and (9) indicate, prices are increasing in marginal costs c_i , decreasing in the elasticity of substitution across locations ($1/t$) and the total number of stores N_{AB} , and increasing in the price of the store located at the border \hat{p}_A and \hat{p}_B . Importantly, the border cost affects prices of interior stores only through its effect on prices at the border stores, and this effect decreases with the distance from the border.

Border Stores.—The final step is to characterize the prices of the border stores, \hat{p}_A and \hat{p}_B . We consider two cases: (i) full market segmentation, for the case where border costs are large enough relative to the equilibrium price gap across the border such that consumers do not cross the border; (ii) partial market segmentation, for the case when some consumers cross the border.

The following set of propositions characterizes border prices in these two cases.

PROPOSITION 2 (Full Segmentation): *If the marginal consumer is at the border, that is*

$$|\hat{p}_A - \hat{p}_B| < b,$$

then national markets are fully segmented and

(i) the prices of stores at the border are given by

$$(10) \quad \hat{p}_A = c_A + \frac{t}{N_{AB}} \frac{3 - \nu_A}{2 - \nu_A}, \quad \hat{p}_B = c_B + \frac{t}{N_{AB}} \frac{3 - \nu_B}{2 - \nu_B},$$

where

$$\nu_A = \frac{\cosh \kappa \left(\frac{N_A - 3}{2} \right)}{\cosh \kappa \left(\frac{N_A - 1}{2} \right)}, \quad \nu_B = \frac{\cosh \kappa \left(\frac{N_B - 3}{2} \right)}{\cosh \kappa \left(\frac{N_B - 1}{2} \right)}.$$

(ii) The difference in border store prices moves one to one with the difference in costs, that is, $\partial(\hat{p}_A - \hat{p}_B)/\partial(c_A - c_B) = 1$.

Proposition 2 corresponds to the case where the difference in prices between border stores, $|\hat{p}_A - \hat{p}_B|$, is smaller than the border cost b . In this case the demand functions are independent of costs on the other side of the border, and markets are completely segmented. The observed difference in prices at the border is also independent from the border cost b , and only provides a lower bound on its true value.

PROPOSITION 3 (Partial Segmentation):

(i) If the marginal consumer for the border stores is located in country A, that is,

$$(11) \quad \hat{p}_A - \hat{p}_B > b,$$

then markets are partially segmented and the prices of stores at the border are given by

$$(12) \quad \hat{p}_A = \frac{(4 - \nu_B)(j_A + b) + (j_B - b)}{(4 - \nu_A)(4 - \nu_B) - 1},$$

$$\hat{p}_B = \frac{(4 - \nu_A)(j_B - b) + (j_A + b)}{(4 - \nu_A)(4 - \nu_B) - 1},$$

where ν_A and ν_B are as before and

$$j_A = (3 - \nu_A)\left(c_A + \frac{t}{N_{AB}}\right), \quad j_B = (3 - \nu_B)\left(c_B + \frac{t}{N_{AB}}\right).$$

(ii) If the marginal consumer for the border stores is located in country B , that is,

$$\hat{p}_B - \hat{p}_A > b,$$

then markets are partially segmented and the prices of stores at the border are given by

$$(13) \quad \hat{p}_A = \frac{(4 - \nu_B)(j_A - b) + (j_B + b)}{(4 - \nu_A)(4 - \nu_B) - 1},$$

$$\hat{p}_B = \frac{(4 - \nu_A)(j_B + b) + (j_A - b)}{(4 - \nu_A)(4 - \nu_B) - 1}.$$

The last proposition illustrates the case where $|\hat{p}_A - \hat{p}_B| > b$. In this case, the demand functions depend on costs on the other side of the border, the border parameter b enters the pricing equations, and changes in relative costs affect both the relative prices of stores at the border as well as the relative markups of these stores.

Discussion.—The model presented in the previous section delivers the following insights. First, if border costs are sufficiently high, markets are perfectly segmented and the magnitude of border costs does not affect pricing decisions. In that case, price differences at the border provide only a lower bound on the true size of border costs. If countries are completely symmetric, this lower bound will be zero, even in the presence of large border costs. Second, stores closest to the border are most sensitive to the border cost. In most of the existing literature, owing to a lack of data, no distinction is made between stores that are close to the border and stores that are far from it. Third, the behavior of relative prices and relative markups is very different in situations of full and partial market segmentation. When markets

are fully segmented, fluctuations in relative costs are reflected mostly in relative prices, with minimal impact on relative markups. By contrast, when markets are partially segmented, fluctuations in relative costs have an impact on both relative prices and relative markups. Finally, equilibrium prices depend on many factors, such as the degree of substitutability across locations (local arbitrage costs), the number of competitors, and the own price elasticity of demand, all of which can vary with location, besides the size of the border cost.

Price Index Construction

We calculate the change in the chain-weighted Törnqvist log price index, $\ln P_t^{TQ}(K, i)$, of category K in store i between period $t - 1$ and t , as

$$\Delta \ln P_t^{TQ}(K, i) \equiv \sum_{k \in K} \ln \left(\frac{p_t(k, j)}{p_{t-1}(k, j)} \right)^{1/2[s_t(k) + s_{t-1}(k)]} \equiv \sum_{k \in K} \omega_t(k) \cdot \Delta \ln p_t(k, j),$$

where the weights $\omega_t(k) = 1/2[s_t(k) + s_{t-1}(k)]$ use the expenditure shares of good k as a fraction of total expenditures on category K in week t , that is,

$$s_t(k) = \frac{\sum_j x_t(k, j) p_t(k, j)}{\sum_{k \in K} \sum_j x_t(k, j) p_t(k, j)} = \frac{\sum_j amt_t(k, j)}{\sum_{k \in K} \sum_j amt_t(k, j)}.$$

In summing over j we use all stores in the United States and in Canada so that differences in the change in the store-level price index arises from differences in the rate of change in prices across stores. There are many weeks, however, when a particular UPC is not sold in a particular store, so we have no recorded price change. In this case, we drop the observation for the store that is missing a price change and reweight the shares across the UPCs for which price information is available in that store. We construct these price indexes for different levels of product classifications: subclass, class, category, and group. For the case of net (gross) prices, we use the net (gross) expenditure shares. Similarly for the imputed net cost (wholesale cost) measure, we use the net (gross) expenditure shares.

Data Description

TABLE A1—DATA SOURCES FOR COVARIATES

| Variable | US Source | Canadian Source |
|-------------------------------|-------------------------|---------------------------------------|
| Population density | 2000 census | 2001 census |
| Store density | 2002 US Economic Census | 2002 Canadian Business Pattern Survey |
| Median household income | 2000 census | 2001 census |
| Share of population 0–19 | 2000 census | 2001 census |
| Share of population 65 and up | 2000 census | 2001 census |
| Share of population black | 2000 census | 2001 census |
| Year opened | Supplied by retailer | Supplied by retailer |

Notes: US 2000 census median household income refers to year 1999 in 1999 US dollars. Canadian 2001 census median household income refers to year 2000 in 2000 Canadian dollars, converted into US dollars at the average exchange rate of 1.4852 Canadian/US dollar.

TABLE A2—NUMBER OF DISTINCT PRODUCTS BY PRODUCT GROUP FOR BOTH COUNTRIES, CANADA AND THE UNITED STATES, AND THE SET OF UNIQUELY MATCHED PRODUCTS

| Product groups | Unique UPCs | | Canada | | United States | | Matched UPCs | |
|-------------------------------------|--------------|---------|--------------|---------|---------------|---------|--------------|---------|
| | Freq. (1) | Percent | Freq. (2) | Percent | Freq. (3) | Percent | Freq. (4) | Percent |
| Alcoholic beverages | 10,038 | 8.03 | 2,268 | 6.88 | 8,173 | 8.3 | 403 | 9.55 |
| Baby food/diapers/baby care | 1,220 | 0.98 | 384 | 1.17 | 930 | 0.94 | 94 | 2.23 |
| Batteries | 94 | 0.08 | 68 | 0.21 | 61 | 0.06 | 35 | 0.83 |
| Books and magazines | 5,361 | 4.29 | 3,908 | 11.86 | 4,266 | 4.33 | 2,505 | 59.35 |
| Candy, gum, and mints | 4,065 | 3.25 | 1,128 | 3.42 | 2,967 | 3.01 | 29 | 0.69 |
| Canned fish and meat | 740 | 0.59 | 203 | 0.62 | 540 | 0.55 | 3 | 0.07 |
| Canned fruits | 228 | 0.18 | 64 | 0.19 | 164 | 0.17 | | |
| Canned vegetables | 459 | 0.37 | 85 | 0.26 | 374 | 0.38 | | |
| Cereal And breakfast | 2,438 | 1.95 | 570 | 1.73 | 1,875 | 1.9 | 7 | 0.17 |
| Cheese | 1,453 | 1.16 | 335 | 1.02 | 1,130 | 1.15 | | |
| Coffee/tea/hot cocoa... | 3,215 | 2.57 | 729 | 2.21 | 2,606 | 2.65 | 120 | 2.84 |
| Commercial bread and baked goods | 4,596 | 3.68 | 492 | 1.49 | 4,111 | 4.18 | 7 | 0.17 |
| Condiments and sauces | 37 | 0.03 | | | 37 | 0.04 | | |
| Cookies/crackers and snacks | 2,869 | 2.29 | 733 | 2.22 | 2,205 | 2.24 | 69 | 1.63 |
| Cough, cold, flu, allergy | 15 | 0.01 | 1 | 0 | 14 | 0.01 | | |
| New age, mixers, bottled water | 4,295 | 3.43 | 1,197 | 3.63 | 3,135 | 3.19 | 36 | 0.85 |
| Deli/food service items | 6,623 | 5.3 | 2,313 | 7.02 | 4,936 | 5.01 | | |
| Dessert and baking mixes | 412 | 0.33 | 121 | 0.37 | 291 | 0.3 | | |
| Detergents and laundry needs | 1,448 | 1.16 | 539 | 1.64 | 963 | 0.98 | 54 | 1.28 |
| Diet, ethnic, and gourmet foods | 3,992 | 3.19 | 901 | 2.73 | 3,397 | 3.45 | 306 | 7.25 |
| Enhancements | 1,086 | 0.87 | 279 | 0.85 | 825 | 0.84 | 18 | 0.43 |
| Floral | 7,360 | 5.89 | 1,719 | 5.22 | 5,914 | 6.01 | | |
| Flour, sugar, corn meal | 122 | 0.1 | 26 | 0.08 | 96 | 0.1 | | |
| Food service | 1,729 | 1.38 | 625 | 1.9 | 1,222 | 1.24 | | |
| Fresh produce | 9,985 | 7.98 | 2,572 | 7.8 | 8,069 | 8.2 | | |
| Frozen breakfast items | 260 | 0.21 | 55 | 0.17 | 207 | 0.21 | 2 | 0.05 |
| Frozen vegetables | 895 | 0.72 | 139 | 0.42 | 757 | 0.77 | 1 | 0.02 |
| Hair care | 1,641 | 1.31 | 582 | 1.77 | 1,061 | 1.08 | 2 | 0.05 |
| Health supplements | 1,356 | 1.08 | 310 | 0.94 | 1,064 | 1.08 | 18 | 0.43 |
| Hispanic products | 1,077 | 0.86 | 68 | 0.21 | 1,013 | 1.03 | 4 | 0.09 |
| Household cleaners | 2,566 | 2.05 | 935 | 2.84 | 1,790 | 1.82 | 159 | 3.77 |
| Housewares | 364 | 0.29 | 95 | 0.29 | 280 | 0.28 | 11 | 0.26 |
| Ice cream and ice | 2,713 | 2.17 | 544 | 1.65 | 2,172 | 2.21 | 3 | 0.07 |
| Fresh bread and baked goods | 959 | 0.77 | 312 | 0.95 | 666 | 0.7 | | |
| Jams, jellies, and spreads | 1,026 | 0.82 | 247 | 0.75 | 798 | 0.81 | 19 | 0.45 |
| Mayo, salad dressings, and toppings | 1,268 | 1.01 | 249 | 0.76 | 1,029 | 1.05 | 10 | 0.24 |
| Meat | 5,604 | 4.48 | 1,301 | 3.95 | 4,370 | 4.44 | | |
| Natural markets | 12 | 0.01 | 12 | 0.04 | 2 | 0 | 2 | 0.05 |
| Oral hygiene | 978 | 0.78 | 303 | 0.92 | 682 | 0.69 | 7 | 0.17 |
| Paper, foil, and plastics | 1,378 | 1.11 | 322 | 0.98 | 1,121 | 1.14 | 65 | 1.54 |
| Pasta and pasta sauce | 1,963 | 1.57 | 362 | 1.1 | 1,624 | 1.65 | 23 | 0.54 |
| Pet food and pet needs | 2,647 | 2.12 | 656 | 1.99 | 2,070 | 2.1 | 79 | 1.87 |
| Pickles, peppers, and relish | 849 | 0.68 | 147 | 0.45 | 709 | 0.72 | 7 | 0.17 |
| Prepared frozen foods | 3,197 | 2.56 | 432 | 1.31 | 2,774 | 2.82 | 9 | 0.21 |
| Ready-to-eat prepared foods | 408 | 0.33 | 57 | 0.17 | 351 | 0.36 | | |
| Refrigerated dairy | 2,841 | 2.27 | 786 | 2.38 | 2,070 | 2.1 | 15 | 0.36 |

(Continued)

TABLE A2—NUMBER OF DISTINCT PRODUCTS BY PRODUCT GROUP FOR BOTH COUNTRIES, CANADA AND THE UNITED STATES, AND THE SET OF UNIQUELY MATCHED PRODUCTS (*Continued*)

| Product groups | Unique UPCs | | Canada | | United States | | Matched UPCs | |
|--------------------------------|--------------|---------|--------------|---------|---------------|---------|--------------|---------|
| | Freq. (1) | Percent | Freq. (2) | Percent | Freq. (3) | Percent | Freq. (4) | Percent |
| Refrigerated foods | 1,201 | 0.96 | 214 | 0.65 | 994 | 1.01 | 7 | 0.17 |
| Refrigerated juice | 435 | 0.35 | 105 | 0.32 | 331 | 0.34 | 1 | 0.02 |
| Respiratory | 537 | 0.43 | 219 | 0.66 | 319 | 0.32 | 1 | 0.02 |
| Rice and beans | 1,177 | 0.94 | 253 | 0.77 | 930 | 0.94 | 5 | 0.12 |
| Salt, seasoning, and spices | 1,133 | 0.91 | 205 | 0.62 | 936 | 0.95 | 8 | 0.19 |
| Salty snacks | 2,367 | 1.89 | 579 | 1.76 | 1,797 | 1.83 | 9 | 0.21 |
| Seafood | 1,901 | 1.52 | 311 | 0.94 | 1,607 | 1.63 | | |
| Shelf stable juices and drinks | 1,267 | 1.01 | 383 | 1.16 | 887 | 0.9 | 3 | 0.07 |
| Shortening and cooking oils | 509 | 0.41 | 112 | 0.34 | 423 | 0.43 | 24 | 0.57 |
| Skin care | 431 | 0.34 | 127 | 0.39 | 314 | 0.32 | 10 | 0.24 |
| Social expressions | 2,028 | 1.62 | 2,028 | 2.06 | | | | |
| Soft beverages | 707 | 0.57 | 167 | 0.51 | 541 | 0.55 | | |
| Soups | 1,351 | 1.08 | 370 | 1.12 | 1,011 | 1.03 | 30 | 0.71 |
| Syrups and pancake/waffle mix | 291 | 0.23 | 65 | 0.2 | 227 | 0.23 | 1 | 0.02 |
| Tobacco and smoking needs | 1,831 | 1.46 | 677 | 2.05 | 1,154 | 1.17 | | |
| Total | 125,048 | 100 | 32,961 | 100 | 98,430 | 100 | 4,221 | 100 |

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