Understanding Movements in Aggregate and Product-Level Real-Exchange Rates*

Ariel Burstein† and Nir Jaimovich‡

August 2009

Abstract

We document new facts on international relative price movements using wholesale price data for common products sold in Canada and United States over the period 2004-2006, and information on the country of production for individual products. We find that international relative prices at the level of individual products are roughly three to four times as volatile as the Canada-US nominal exchange rate at quarterly frequencies. Aggregate real-exchange rates, constructed by averaging movements in international relative prices for individual goods, closely follow the appreciation of the Canadian dollar over this period. These patterns hold for matched products that are produced locally in each country, as well as for goods produced in one country and traded to others. The large movements in international relative prices for traded goods are in conflict with the hypothesis of relative purchasing power parity, but instead point to the practice of pricing-to-market by exporters.

In light of these findings, we construct a simple model of international trade and pricing-to-market that rationalizes the observed movements in product- and aggregate real-exchange rates for both traded and non-traded products. The international border plays a key role in accounting for our pricing facts by segmenting competitors across countries.

*We thank Mai Bui, Jim Castillo, Yamila Simonovsky, and Daniel Weinstein for superb research assistance with our data. We also thank Andy Atkeson, Charles Engel, Emi Nakamura and David Weinstein for very useful comments.

†UCLA and NBER.

‡Stanford University and NBER.

1. Introduction

One of the central questions in international macroeconomics is why relative prices across countries, as measured by real-exchange-rates (RERs), are so volatile over time. This question is at the heart of the discussions on optimal exchange rate policy and on the role of the border in creating frictions to the international trade of goods.

What do simple models of price setting imply for movements in international relative prices? Consider first the implications of models with perfect competition or models with imperfect competition and constant markups, in which prices change one-to-one with movements in marginal production costs. These models imply that the relative price of a traded good produced in a common location and sold in two countries should remain constant over time — the hypothesis of relative purchasing power parity (relative PPP). However, a large body of empirical work suggests that relative PPP does not provide an accurate representation for movements in relative prices of many goods (see, for example, the survey in Goldberg and Knetter 1995). Another implication of models with constant markups is that, if all goods can be traded freely across countries, consumer-price-based RERs should be constant over time.

In order to account for the large observed movements of RERs in the data, researchers have departed from the constant markup costless-trade benchmark in two directions. First, they have taken into consideration that many goods and services are not traded, and that even traded goods include a substantial non-traded distribution component. Changes in relative prices across countries for non-traded goods can reflect movements in relative production or distribution costs across locations. Second, researchers have considered models of imperfect competition with variable markups, in which movements in international relative prices are the outcome of changes in relative markups. This is the practice of pricing-to-market by which exporters systematically vary the markup at which they sell their output in two different locations.

In this paper, we use detailed product-level data on prices in Canada and the US to document new stylized facts on movements in international relative prices, and to assess the role of pricing-to-market by individual producers in accounting for these relative price movements. We then use this set of facts as a guide to design a model of trade and international prices.

Our empirical work is based on scanner data from a major retailer that sells primarily nondurable goods in multiple locations in Canada and the US.[1] For each product and each location, we observe weekly wholesale prices paid by the retailer during the period 2004 through 2006. We complement this information by constructing a set of matched products sold in Canada and the US that share identical bar codes. We also construct a broader set of matched products with different bar codes but a common manufacturer, brand, and other characteristics. For roughly $10,000$ of these matched products, we identify the country of production (separately for Canadian and US sales), at one point in time. Roughly half of our matched products are internationally traded, in that they are produced in a common location for sales in Canada and the US (e.g. Pantene shampoo produced in the US, Barilla tortellini produced in Italy, for both Canadian and US sales). The other half of our matched products are non-traded internationally in that they are produced in a different location for sales in Canada and the US (e.g. Coca-Cola produced in Canada for Canadian sales, and in US for US sales).

Our main findings from our data can be summarized as follows. First, movements in *aggregate RERs*, constructed by averaging changes in relative prices across countries (expressed in a common currency) over a large set of matched products, closely track movement in the Canada-US relative unit labor costs and nominal exchange rates. Hence, our price data is consistent with evidence in Mussa (1986) and Engel (1999) that movements in aggregate RERs and nominal exchange rates are highly correlated.

Second, movements in international relative prices are not accounted for by large movements in nominal exchange rates and small movements in nominal prices. In our data, nominal prices of individual products display large and frequent movements (consistent with the evidence in Bils and Klenow 2004 for US consumer prices). Moreover, changes in international relative prices at the level of individual products — *product-level RER*s, are very large, roughly four times as volatile (at quarterly frequencies) as the Canada-US nominal exchange rate.

Third, movements in product-level RERs are pervasive even for traded products that are manufactured in a common location and sold in multiple locations. Under the assumption that products that are produced in a common location and sold in multiple locations are subject to common changes in marginal cost, this finding suggests that producers and wholesalers in our data engage in substantial pricing-to-market. The practice of pricing-

[1] Data from this retailer have been used by Chetty, Looney, and Kroft (2008), Eichenbaum, Jaimovich, Rebelo (2008), Einav, Leibtag and Nevo (2008), and Gopinath, Gourinchas, Hsieh (2008).

to-market in our data displays the following two patterns. First, even though on average, product-level RERs for traded products closely track the Canada-US nominal exchange rate, the idiosyncratic, product-specific component of pricing-to-market is much more important: product-level RERs for these products are roughly four times as large as exchange rate movements. Second, pricing-to-market is more prevalent across regions in different countries than across regions within the same country. In particular, movements in product-level RERs are roughly twice as volatile across countries than within countries.

Our empirical findings contribute to a recent and rapidly growing literature documenting the behavior of international relative prices using detailed product-level information (see, e.g. Crucini, Telmer, and Zachariadis 2005, Crucini and Telmer 2007, Crucini and Shintani 2008, Broda and Weinstein 2008, and Gopinath, Gourinchas, and Hsieh 2008). The main focus of these papers is to study differences in price levels across locations, as well as the volatility and persistence in relative prices. Our empirical contribution to this work is to measure the extent to which movements in relative prices of matched individual products across locations reflect pricing-to-market by producers and wholesalers. We can do so because of three unique features of our data. First, we match individual products sold in multiple locations. Second, we observe wholesale prices (as opposed to retail prices, which include substantial distribution costs). Third, we identify the country of production of individual products that are sold in Canada and the US. Without this information, one cannot distinguish to what extent movements in relative prices of matched products across locations reflect the practice of pricing-to-market by individual producers and wholesalers, as opposed to movements in production or retail costs across locations. Fitzgerald and Haller (2008), like us, provide evidence of pricing-to-market by individual exporters in response to changes in nominal exchange rates, using domestic and export prices of individual Irish producers.[2]

In light of our empirical findings, we then construct a simple model of international trade and pricing-to-market that we use to identify key forces to rationalize our stylized facts on

[2] There is also a large body of work that documents the extent of pricing-to-market using more aggregated price data at the level of good categories or industries — either price indices produced by National Statistical agencies, or unit values (see, e.g. Atkeson and Burstein 2008 and the survey in Goldberg and Knetter 1995). Measuring the extent of pricing-to-market using product-level data for matched products has an advantage over using aggregate price indices, since these indices typically include products that are not common across countries. Therefore, movements in international relative prices based on aggregate price indices can result from differences in the product composition of the indices, and not from changes in relative price across countries for common goods. Engel and Rogers (1996) and Gorodnichenko and Tesar (2008) use price indices at the level of good categories to assess the international role of the border in accounting for movements in RERs.

aggregate and product-level RER movements. Our model follows the recent work of Atkeson and Burstein (2007 and 2008), that builds on the pricing-to-market literature pioneered by Dornbusch (1987) and Krugman (1987),[3] and upon the Ricardian models of international trade with heterogeneous producers and variable markups by Bernard, Eaton, Jensen, and Kortum (2004). In particular, we extend the models in Atkeson and Burstein (2007 and 2008) along three dimensions. First, we introduce time-varying demand and cost shocks in order to account for idiosyncratic movements in product-level RERs that are larger than movements in relative unit labor costs and aggregate RERs. Second, we introduce multiple regions within countries in order to account for the movements in relative prices within and across countries. Third, we endogenize the choice to serve foreign markets via exports (subject to international trade costs) or multinational production (subject to a loss in productivity) to account for the price movements of both traded and locally-produced matched products in our data.

We provide a simple analytical characterization to illustrate the model's ability to match our key pricing observations. The main force in the model is that, with Bertrand competition and limit pricing, prices are determined by idiosyncratic demand shocks and by the marginal cost of the latent competitor. Pricing-to-market is more prevalent across countries than within countries if either one of the two following conditions holds. First, idiosyncratic cost and demand shocks are less correlated across countries than within countries. Second, exporters are more likely to face the same latent competitor (with a common cost shock) within a country than across countries, a feature that is largely determined by the size of international trade costs.

In the model, a lower likelihood that exporters compete with the same latent competitor in both countries carries two additional implications. First, it increases the volatility of product-level RERs across countries, because producers facing different latent competitors across countries set domestic and export prices that are uncorrelated. Second, as in Atkeson and Burstein (2008), it implies that prices are more responsive to the local wage in the destination country, leading to larger movements in aggregate RERs in reaction to changes in relative costs across countries. Combining these two results, the model predicts a negative relation between the international correlation of product-level price changes and the size of movements of aggregate RERs. This prediction is supported by observed differences in price

[3] See Alessandria (2004), Bergin and Feenstra (2001), Corsetti and Dedola (2005), and Drozd and Nosal (2008) for other recent models of pricing-to-market.

movements across product categories in our data.

We then relax some of the assumptions that make the model analytically tractable, and solve numerically a parameterized version that matches key observations on the volume of trade and intra-national movements of prices in Canada and the US. We show that our analytical results are largely unaffected, and that our model can to a large extent can account quantitatively for our observations on product-level and aggregate RERs. We also discuss alternative models that would fail to account for our stylized facts along several dimensions.

Our paper is organized as follows. Section 2 describes our data. Section 3 reports our main findings on international price movements. Section 4 presents our model. Section 5 examines the pricing implications in an analytically tractable version of the model. Section 6 presents the quantitative results of a parameterized version of our model. Section 7 concludes.

2. Data Description

Our analysis is based on scanner data from a large food and drug retail chain that operates hundreds of stores in Canadian provinces and US states. The stores are located in British Columbia, Alberta and Manitoba, in Canada, and multiple US states covering a large area of the US territory. We have weekly data over the period 2004-2006, covering roughly 60,000 products defined by their universal product code (UPC).

The retailer classifies products as belonging to one of 200 categories. We focus on 93 product categories, including processed food, beverages, personal care, and cleaning products. We exclude "non-branded" products such as vegetables and fruits, deli sandwiches, deli salads, and sushi, for which the information on country-of-origin is harder to identify. We also leave-out magazines because advertising revenues account for a substantial share of the publisher's total revenues.

For each store we have information on quantities sold, sales revenue, and the retailer's cost of purchasing the goods from the vendors, net of discounts and inclusive of shipping costs. Using this data, we construct retail and wholesale prices, as described in Appendix 1. Wholesale prices are the closest measure of producer prices in our data.

Our analysis focuses primarily on wholesale prices in order to abstract from local retail distribution services and other retail pricing considerations such as multi-product pricing. Local distribution services are substantially less sizeable at the wholesale level.[4] In Section

[4]Burstein, Neves, and Rebelo (2003) use US input-output data to measure distribution margins at the

3.X, we briefly report our central empirical findings based on retail prices.

Note that, given that our data covers one single retail chain, we are not able to measure the extent of pricing-to-market by producers and wholesalers across different retail chains for common products.

2.1. Aggregation across space and time

Aggregation across space The retail chain groups different stores into relatively concentrated geographic areas within a province or a state that share a common pricing policy. Based on information from the retailer and on our own calculations, we identify 17 pricing regions in Canada and 73 pricing regions in the US. Given the similarity of wholesale and retail prices across stores within pricing regions, we choose to focus on these as our geographic unit. Considering all individual stores within each pricing region would substantially increase the size of our dataset without essentially adding new information.

We thus construct a weekly wholesale price for each pricing region as the median wholesale price across stores within the pricing region. For most products in our data, there is considerable variation in wholesale prices across pricing regions. This is because vendors or wholesalers charge different prices for the same product in different regions.

Our baseline statistics are computed for the 5 pricing regions in British Columbia in Canada, and 14 pricing regions in Northern California in the US. These regions are roughly comparable in geographic scope and cover the stores where the country of production was identified (more on this below). We also report our statistics based on the pricing regions in the *Center-West* geographic area. This includes all 17 pricing regions in Canada, and 51 pricing regions in the US located in California, Oregon, Washington, Idaho, Montana, and Wyoming, chosen to match roughly the geographic coverage in Canada.

Aggregation across time Our statistics are based on prices at quarterly frequencies. These are constructed as average weekly prices within the quarter. In doing so, we are abstracting from sales and promotions that give rise to highly temporary price changes.[5]

wholesale and retail levels. For non-durable goods in 1997, the total distribution margin is 46%, and the wholesale distribution margin is only 16%. For groceries and related products, the US Census of Wholesale reports a distribution margin of roughly 16%.

[5] We also constructed our price statistics using median and mode weekly prices within each quarter. These lead to even larger movements in product-level RERs (both within and across countries), and do not have a significant impact on the movements of aggregate RERs.

In computing our price statistics, we abstract from very short-lived products in our data, and only include those with at least four consecutive growth rates, and product categories with at least 50 growth rates per quarter. Our results are largely unchanged to variations in the filtering criteria.

2.2. Matching products

In order to measure movements in international relative prices, we need to match products in Canada and the US. We proceed in two steps. First, we match products that have identical UPC codes in both countries. This gives us $1,213$ identical product matches across countries.

Since our emphasis is on understanding price fluctuations over time, as opposed to differences in price levels at a point in time, we also consider a broader set of internationally matched products beyond these identical products. Our key assumption in this matching procedure is that two products that are matched and produced in a common location, share a common percentage change in marginal cost for sales in Canada and the US. Under this assumption, changes in relative prices across locations for goods produced in a common location can be interpreted as movements in relative markups by individual producers (i.e., pricing-to-market).

Specifically, to broaden the set of matched products, we include items that have different UPC codes but share in both countries the same manufacturer, brand, and at least one additional characteristic in the product description. Our procedure does not require that matched products share a common size and exact product description. Given the degree of arbitrariness in our matching process, we classify our matches from "conservative" to "liberal" (more on this below).

Our conservative matches include, for example, "Schweppes Raspberry Ginger Ale 2Lts" in Canada with "Schweppes Ginger Ale 24 Oz" in the US, "Purex Baby Soft" in Canada with "Purex Baby Soft Classic Detergent" in the US, "Crest toothpaste sensitivity protection" in Canada with "Crest sensitivity toothpaste whitening scope" in the US, and "Gatorade strawberry ice liquid sports drink" in Canada with "Gatorade sports drink fierce strawberry" in the US. This process yields roughly $14,000$ product matches across countries.

Our baseline results use the union of the set of identical and the set of conservative product matches. To show that our main findings are not driven by non-identical matches, we also report results based on identical product matches (if we have sufficient observations). In our sensitivity analysis, we also report our results based on liberal matches. Our findings are largely robust to these alternative matching procedures.

2.3. Inferring country of production

Next, we identify the country of production for matched products sold in Canada and the US.[6] For each of our matched products our procedure was as follows. First, in the US, we used the country-of-origin label information that was available in the retailer's online store for sales in Northern California. Second, in Canada, given that the country-of-origin information was not available on-line, we hired two research assistants who physically visited the retailer store in Vancouver and recorded the country-of-origin label information.[7] Third, our research assistants verified the label information by calling many of the individual manufacturers.[8] This procedure was carried out during the months of May-June 2008.

We group our matched products into four country-of-production sets. The first set consists of matched products that are produced in the US for both US and Canadian sales, such as Pantene shampoo, Ziploc bags, and Rold Gold Pretzels. The second set consists of matched products that are produced in Canada for both US and Canadian sales, such as Sapporo beer, Atkins advantage bar, and Seagram whisky. The third set consists of matched products that are produced in the US for US sales and in Canada for Canadian sales, such as Coca-Cola, Haagen-Dazs ice-cream, Yoplait yoghurt, and Bounce softener. The fourth set consists of matched products that are produced in other countries for US and Canadian sales, such as Myojo instant noodles (Japan), Absolut vodka (Sweden), and Barilla tortellini (Italy).

There are two important caveats in our approach. First, it is possible that a product's country of production varies over time. Second, it is possible that a product's country of production varies across regions within the US and Canada. With respect to the first

[6] We abstract from retailer brands and non-branded products because we lack information on the identity of the manufacturer.

[7] Given that our retail chain does not sell liquor products in Vancouver, we obtained their country-of-origin information from other stores. We use this information when examining price movements of liquor products in other Canadian cities.

[8] According to the US Federal Trade Commission's rules, for a product to be labelled Made in USA, the product must be "all or virtually all" made in the U.S. In Canada we do not know of such a legal label requirement. If there was a bias in reporting goods as locally produced when they are not, then products that are labelled as foreign produced would be very likely to be so. Hence, given that our inference on pricing-to-market is based on goods that are produced in a common country, we believe that for these good the country-of-origin information is quite accurate. Note also that foreign produced goods can potentially have a local packaging component. As discussed in Section 5.1, these local distribution components would have to be extremely large to account entirely for the large movements in RERs observed in our data.

caveat, we have informal evidence based on interviews with the retail managers that for most products there is small variation over time in the country of production. To address the second caveat, we define our baseline geographic area to include only the pricing regions in British Columbia and North California, where the information on country of production was obtained.

2.4. Descriptive statistics

Table 1 provides descriptive statistics for our matched products. We separately report the information for our identical and conservative matches, for the set of pricing regions in the Center-West and for those in British Columbia and North California.

Row 1 shows that our set of identical matches covers roughly 5% of the retailer's total sales (evaluated at wholesale prices) on our set of product categories, and the union of conservative and identical matches covers 52% of total expenditures in Canada and 36% in the US.[9]

Rows 2-7 summarize our country of production information for the set of products we cover. Rows 2-4 report expenditure shares by country of production, and rows 5-7 report the number of products by country of production. These shares display a significant degree of home bias in consumption, and reveal that Canadian imports from the US account for a larger fraction of their expenditures than US imports from Canada. In particular, based on our set of identical and conservative matches, 90% of expenditures in the US (and roughly the same share of matched products) are produced domestically. Imports from Canada and the rest of the world (ROW) account for only 1% and 10% of expenditures, respectively. In Canada, roughly two-thirds of expenditures in our set of products are produced domestically (or half of the number of products). Imports from the US account for an expenditure share of 30%, and imports from ROW account for an expenditure share of only 3%.[10]

Rows 8-11 report the number of matched products, divided into our four country-production sets. We have roughly $1,000$ identical matches in the Center-West area, and 800 in British-Columbia and Northern California. Including conservative matches increases the number of

[9] We do not cover 100% of the expenditures for the following three reasons. First, we abstract from retailer brands. Second, many products cannot be matched across Canada and the US. Third, for some of the matched products we lack information on the country of production.

[10] Our data provide a good representation of bilateral trade shares for Canada and US based on more aggregate data. In particular, the import shares reported in Table 1 are similar to OECD-based import shares for comparable industries including chemicals, food products, beverages, and tobacco over the period 1997-2002.

matches to 11,000 in Center-West and 9,000 in British-Columbia and Northern California.[11]

Of these identical and conservative matched products, roughly half are produced in the US for both US and Canada sales, and as many as 45% are produced domestically in each country. The share of matched products that are exported either by Canada or by other ROW countries is less than 5%, and hence is significantly smaller than the number of those that are exported by the US or produced domestically. Therefore, our statistics for Canadian and ROW exporters are more prone to small sample limitations.

3. Data: Findings on Price Movements

In this section we report our central empirical findings on aggregate- and product-level RER movements and on the extent of pricing-to-market. We first show that movements in Canada-US aggregate RERs closely track relative unit labor costs. For exported products that are produced in a common country and sold in both countries, this is evidence of pricing-to-market by individual producers or wholesalers. Second, we show that these movements in relative prices are not the result of sticky nominal prices and volatile exchange rates. Instead, product-level RERs are very volatile, even for exported products, because prices changes are frequent, large, and not very correlated across international locations. Third, we show that movements in relative prices are larger between countries than between pricing regions of the same country. We provide extensive robustness checks to these three findings. Finally, we show that the extent of pricing-to-market differs for exporters in US, Canada and the ROW, and that exported goods in product categories with low international correlation of price changes also tend to be the ones that experience large aggregate RER movements in response to a change in relative unit labor costs. These two last findings provide some support for the model we develop later.

Definitions Our data contains time series information on prices of individual products sold in multiple regions in US and Canada. We denote individual products by $n = 1, 2, ..$, time periods by $t = 1, ..., T$, countries by $i = 1$ (US) and $i = 2$ (Canada), and regions by $r = A, ..., R_i$.

The price (in US dollars) of product n sold in country i, region r, in period t, is denoted

[11] Note that the total number of conservative matches exceeds the number of unique products in Rows 5-7, because some products can be matched more than once. For example, Coca-Cola 2lt in Canada is matched with Coca-Cola 12 Oz and Coca-Cola 24 Oz in the US.

by P_{nirt}. We refer to relative prices across regions for individual products as product-level RERs. The relative price of product n between region r in country i and region r' in country j is denoted by:

$$Q_{nijrr't} = P_{nirt}/P_{njr't}.$$

The logarithmic percentage change in the price of an individual product between periods t and $t-1$ is denoted by:

$$\Delta P_{nirt} = \log\left(P_{nirt}\right) - \log\left(P_{nirt-1}\right).$$

Similarly, the percentage change over time in the relative price between region r in country i and region r' in country j is denoted by:

$$\Delta Q_{nijrr't} = \log\left(Q_{nijrr't}\right) - \log\left(Q_{nijrr't-1}\right) = \Delta P_{nirt} - \Delta P_{njr't}.$$

We focus on percentage price changes of relative prices, as opposed to dollar changes in price levels, because movements in relative prices immediately indicate deviations from relative PPP. For products that are produced in a common location and hence share a common change in marginal cost, $\Delta Q_{nijrr't} \neq 0$ indicates that producers and wholesalers price-to-market by varying their markups across these two locations.

We also construct a measure of movements in aggregate RERs across countries by averaging the change in product-level RERs over a large set of individual products and pairs of regions across the two countries. Aggregate RERs average-out the idiosyncratic changes in product-level RERs, and capture the time-varying components that are common to many products. More specifically, the change in the Canada-US aggregate RER between periods $t-1$ and t for products belonging to a set N and sold in both countries is defined as

$$\Delta Q_t = \sum_{n \in N} \sum_{r'=A}^{R_1} \sum_{r=A}^{R_2} \psi_{nrr't-1} \Delta Q_{n21rr't}, \tag{3.1}$$

where $\psi_{nrr't}$ denotes the average expenditure share of product n in region r in country 1 and region r' in country 2, in period t. These shares add up to one across all products in the set N and pairs of regions. Further details are provided in Appendix 1.[12]

[12] We also constructed aggregate RERs based on aggregate price indices defined as weighted-average changes in prices over a set of products and regions within a country, following the procedure of the US Bureau of Labor Statistics. The resulting movements in aggregate RERs are very similar to those constructed using (3.1).

3.1. Aggregate Real Exchange Rates

Figure 1 depicts the cumulative movement of aggregate RERs, separately for each of the following country-of-production sets: all exported products, US exported products, Canada-ROW exported products, and domestically produced products.[13] We focus on the pricing regions in British Columbia and Northern California, where our information on country-of-origin was obtained.

Over our sample period $2004 - 2006$, relative unit labor costs as constructed by the OECD increased in Canada by roughly 15% (mainly accounted for by an appreciation of the Canadian dollar relative to the US dollar of a similar magnitude). Over this period, prices in Canada rose substantially relative to prices in the US, leading to the observed increase in Canada/US aggregate RERs in the four panels in Figure 1. For example, for exported products the aggregate RER rose by as much as roughly 13% from 2004 Q1 to 2006 Q4. For domestically produced products, the aggregate RER increased by roughly 10%. The magnitude of the movements in aggregate RERs is quite similar if we consider identical matches or our broader set of identical plus conservative product matches.[14]

Recall from the discussion above that models of perfect competition or constant markups in which producers change their price in proportion to changes in marginal cost can account for aggregate RER movements for goods that are locally produced in each country. In contrast, these models cannot account for the aggregate RER movements of goods that are produced in one common country for sales in both countries. The large aggregate-RER movements of these goods point to models of pricing-to-market in which exporters systematically raise markups in Canada relative to the US

Sticky prices and aggregate RERs If prices are sticky in the buyer's currency, an appreciation of the Canadian dollar mechanically increases Canadian prices relative to US prices measured in the same currency, as observed in Figure 1. In our data, however, individual wholesale prices in Canada and the US move very frequently. The frequency of price adjustment for our median product based on weekly prices implies that prices typically change every two weeks. We also computed frequencies of price adjustment based on price

[13] We do not consider separately Canada and ROW exported products because the number of products is too low to smooth-out the idiosyncratic movements in prices.

[14] The common components of intra-national relative price changes across products are much smaller. In particular, intra-national aggregate RERs, constructed by averaging movements in product-level RERs across many products for pairs of regions within countries, are roughly constant over time.

series exclusive of sales or other highly temporary variation. Here we follow Eichenbaum, Jaimovich and Rebelo (2008) and construct reference prices as the modal, or most common price across weeks within each quarter. The median frequency of adjustment for quarterly modal prices is 0.5 in Canada and US, so that prices change on average every 2 quarters. Moreover, the fraction of matched products for which neither the Canadian mode price nor the US modal price change, as required by the explanation above, is only 25%.[15] The fact that prices in our data change quite frequently suggest that sticky local currency prices as a source of pricing-to-market has at most a limited role in accounting mechanically for the two-years steady rise in Canada-US aggregate RERs in Figure 1.

3.2. International Product-level Real Exchange Rates

We now show that, underlying the smooth rise in Canada-US aggregate RERs displayed in Figure 1, there are very large idiosyncratic movements in product-level RERs.

To fix ideas, Figure 2 depicts movements of prices and product-level RERs for one identical matched product in our sample. The product belongs to the product category "Tea" and is produced in the US for sales in both the US and Canada. The top panel displays the 11 quarterly growth rate of prices (all expressed in US dollars), ΔP_{nirt}, in three regions: two regions in the US (both in northern California), and one region in Canada (in British Columbia). The bottom panel displays the percentage change in the relative price between the two US regions, $\Delta Q_{n11rr't}$, and one region in the US and one in Canada, ΔQ_{n12rrt}. The lower panel also displays quarterly changes in relative unit labor costs between Canada and the US. One can observe for this particular product that relative prices between Canada and the US change by large magnitudes over time, more so than relative unit labor costs.

Figure 3 presents histograms of the movements in product-level RERs between pairs regions in British Columbia and Northern California like the ones displayed in Figure 2, but now across our entire set of identical and conservative matched products. The upper panel considers only products that are produced in a common country and exported to the other country. The lower panel considers matched products that are produced locally in each country and are not internationally traded. Observe that in both panels, movements in product-level RERs are quite large.

[15] Gopinath and Rigobon (2008) also document large changes of US import and export prices for individual products. For processed food items in their data, the frequency of price adjustment is roughly as large as in our data.

To quantify this information, we construct a measure of volatility of international product-level RERs (i.e. between regions of different countries). The international variance of product-level RERs over a set of products N is defined as:

$$\text{Var}^{\text{inter}} = \sum_{n \in N} \sum_{r=A}^{R_1} \sum_{r'=A}^{R_2} \sum_{t=1}^{T-1} \frac{1}{\bar{n}} \left(\Delta Q_{n12rr't} - \overline{\Delta Q_{inter}} \right)^2 \ , \tag{3.2}$$

where $\overline{\Delta Q_{inter}}$ denotes the average change in relative prices over these products, regions, and time periods, and $\bar{n}$ denotes the number of observations over which this statistic is evaluated. We report in Row 3 of Table 2 the standard deviation of international RERs, $\sqrt{\text{Var}^{\text{inter}}}$, instead of the variance, to facilitate the comparison of our results with standard measures of nominal and real-exchange rate volatility. We report separately our statistics for the various country-of-production sets, for identical and conservative product matches.

Combining all our location-of-production sets, the standard deviation of international product-level RERs is 13% for either our identical or identical plus conservative matches. To put this figure in perspective, the standard deviation of quarterly changes in the Canada-US relative unit labor costs, nominal exchange rate, and the CPI-based RER between 1998 and 2007 is roughly 3%. Our finding that product-level RERs are highly volatile over time is consistent with the evidence in Crucini and Telmer 2007 and Broda and Weinstein 2008.

Product-level RERs across countries are very volatile not only for matched products that are produced domestically in each country, but also for matched products that are produced in one country and exported to other countries. In particular, based on our set of identical and conservative matches the international standard deviation of product-level RERs is equal to 11% for US exported products, 14% for Canadian exported products, 14% for exported products by other ROW countries, and 13% for matched products that are produced domestically in each country. Product-level RERs are also very volatile if we only consider identical product matches.

The large observed idiosyncratic movements in RERs across countries for products that are locally produced in each country could simply reflect movements in marginal costs across production locations. However, for products that are produced in one country and exported to others, this is evidence of pricing-to-market by which exporters vary their markups across location. These movements in relative markups do not arise mechanically due to sticky prices in local currency, but instead are the result of large differences in nominal price fluctuations across countries.

3.3. Inter- and Intra-national product-level real exchange rates

For our selected "Tea" product in Figure 2, one can observe that relative prices are more volatile between the pricing region in British Columbia and Northern California than between two pricing regions in Northern California. More generally, Figure 3 displays histograms of relative price movements across our entire set of identical and conservative matched products, between pairs of pricing regions in British Columbia and Northern California, as well as between pairs of pricing regions within British Columbia and within Northern California. Again, movements in product-level RERs are larger between countries than between pricing regions of the same country.

To quantify this pattern, we define the intra-national (i.e. between regions of the same country) variance of product-level RERs in country i analogously to $\text{Var}^{\text{inter}}$ in (3.2), as

$$\text{Var}_i^{\text{intra}} = \sum_{n \in N} \sum_{r=A}^{R_i} \sum_{r' \neq r}^{R_i} \sum_{t=1}^{T-1} \frac{1}{\bar{n}} \left(\Delta Q_{niirr't} - \overline{\Delta Q_{intra,i}} \right)^2 . \tag{3.3}$$

Rows 1 and 2 in Table 2 report the standard deviation of intra-national product-level RERs, $\sqrt{\text{Var}_i^{\text{intra}}}$ for our various country-of-production sets.

Product-level RERs are close to two times as volatile across countries than within countries. For example, based on identical and conservative matches, the standard deviation of product-level RERs for all exported products is 5% within Canada, 6% within the US, and 11% across countries.[16] If we consider only identical product matches, intra-national product-level RERs are slightly more volatile, but still substantially less volatile than international product-level RER.

These statistics are constructed based only on the pricing regions in British Columbia and Northern California. We can extend the geographic scope of our analysis by considering all pricing regions in our data. We follow the literature (see e.g. Engel and Rogers 1996) and consider the following regression. The dependent variable is the standard deviation of product-level RERs across all pairs of pricing regions within and across countries. The independent variables include a constant, the logarithm of distance between the pairs of regions, product-category dummies, and a dummy that equals one if the two regions lie in different countries. The distance coefficient is positive and significant (suggesting that regions that are farther apart experience larger deviations from relative PPP), and the dummy coefficient

[16] Our finding that $Var_{US}^{\text{intra}} > Var_{Can}^{\text{intra}}$ echoes the findings in Gorodnichenko and Tesar (2008) who use more aggregated price data.

is equal to 5.8% and statistically significant. Note that the value of this dummy coefficient is very similar to the difference in the standard deviation of inter- and intra-national product-level RERs based only on data from British Columbia and Northern California. This confirms our previous findings that pricing-to-market is roughly twice as prevalent across countries than within countries.

To better understand why relative prices are more volatile across countries than within countries, we can express the ratio of international to intra-national RER variances defined in (3.2) and (3.3) as

$$\frac{\text{Var}^{\text{inter}}}{\text{Var}_i^{\text{intra}}} = \left(\frac{\text{Var}_1^{\Delta P} + \text{Var}_2^{\Delta P}}{2\text{Var}_i^{\Delta P}}\right)\left(\frac{1 - \frac{2\left(\text{Var}_1^{\Delta P}\right)^{0.5}\left(\text{Var}_2^{\Delta P}\right)^{0.5}}{\text{Var}_1^{\Delta P}+\text{Var}_2^{\Delta P}}\text{Correl}^{\text{inter}}}{1 - \text{Correl}_i^{\text{intra}}}\right). \tag{3.4}$$

Here, $\text{Var}_i^{\Delta P}$ denotes the variance of price changes ΔP_{nirt} for products sold over the various pricing regions in country i. $\text{Correl}_i^{\text{intra}}$ denotes the correlation of price changes between the various pairs of regions in country i, and $\text{Correl}^{\text{inter}}$ denotes the correlation of price changes between pairs of regions in country 1 and country 2.

In our data, the variance of US-dollar denominated nominal price changes, $\text{Var}_i^{\Delta P}$, is roughly equal in the US and Canada. For exported product matched, for example, the standard deviation of price changes is 7.8% in Canada and 8.1% in the US. Hence, from (3.4), differences in intra- and international RER volatilities are accounted for by differences in the correlation of price changes within and across countries. Given that $Var^{\text{inter}} > Var_i^{\text{intra}}$, we must have that price changes are more correlated within than across countries. Indeed, Rows 4-6 in Table 2 show that, based on identical and conservative matches for all exported products, $\text{Correl}_{US}^{\text{intra}} = 0.73$, $\text{Correl}_{Can}^{\text{intra}} = 0.80$, and $\text{Correl}^{\text{inter}} = 0.09$. These patterns are similar for goods that are locally produced in each country.

Hence, the key challenge involved in understanding the observed differences in the volatilities of product-level RERs within and across countries is to explain why price movements are less correlated across countries than within countries.

3.4. Robustness

Table 3 reports our statistics on product-level RERs if we change our baseline procedure along several dimensions.

First, we vary our set of matched products by including 'liberal matches', which loosen the conditions that define a matched product. Recall that our key assumption in this matching procedure, in order to assess the extent of pricing-to-market, is that two products that are matched and produced in a common location share a common percentage change in marginal cost for sales in Canada and the US. Liberal matches include pairs of goods that are produced by the same manufacturer but share fewer characteristics than under our benchmark matching procedure. For example, we match all pairs of Gatorade sport drinks even if they are of different flavors. This procedure increases the number of matched products at the expense of increasing the subjectiveness of our matched procedure. Panels A reveals that our key statistics remain roughly unchanged. All remaining panels in Table 3 are based on our set of identical and conservative product matches.

Second, we vary the geographic scope in the construction of our statistics. Panel B is based on the pricing regions in the *Center-West* geographic area for our identical and conservative product matches (recall that in Panel C of Table 2, we considered this geographic area only for identical product matches). Panel C is based on a single pricing region in both British Columbia and Seattle which, given their geographic closeness, increases the likelihood that goods consumed in these districts with a common country-of-origin are actually produced in the same location (and hence, share a common change in marginal cost). Panel D is based on a single pricing region in British Columbia, Manitoba, Northern California, and Illinois, to ensure that our intra-national price findings are not driven by sampling prices from nearby pricing regions. Our findings that movements in product-level RERs are large, even for exported products, and roughly two times as volatile across countries than within countries, are robust to these variations in geographic coverage.

Third, we construct our measure of product-level RERs net of movements in the category-wide RER. Panel E shows that our findings are roughly unchanged relative to our baseline results, highlighting the important role of individual product-level RER movements as opposed to category-wide price movements driven, for example, by seasonalities. Our findings also are robust to constructing movements in product-level RERs net of movements in nominal wages in each country (see Panel F), as in Engel and Rogers (1996). We obtain similar results if we define product-level RERs as ratios of nominal prices, without converting them into a common currency.

Fourth, we construct our statistics based on retail prices instead of wholesale prices. As previously documented in Eichenbaum, Jaimovich and Rebelo (2008), modal retail prices in this dataset change less frequently than wholesale prices. However, the fraction of matched products for which either the Canadian or the US modal price change in a given quarter is still quite high, and equals 0.62 (recall that this fraction is 0.75 using wholesale prices). Moreover, Panel G (identical matches) and Panel H (identical and conservative matches) in Table 3 reveal that movements in product-level RERs based on retail prices are also very large, three to four times as volatile as relative unit labor costs.

Finally, in those cases of our robustness analysis where we have enough data to compute aggregate RERs that smooth-out idiosyncratic product-level price movements, we find that movements of aggregate RERs in response to changes in relative unit labor costs resemble those under our baseline configuration in Figure 1.

3.5. Additional Findings

Comparison across locations of production The results in Table 2 reveal differences in the measures of intra- and inter product-level RER volatilities and price correlations for products belonging to our four different country-of-production sets. Directly comparing these measures, however, is complicated by the fact that most of the categories in our data do not contain producers from all four possible production sets. For example, our product category "Dry Dog Food" only contains matches for products that are produced domestically in each country. This implies that when we compare our statistics across country-of-production sets, we are mixing different between country-of-production and differences between product categories.

In order to address this concern, we construct our statistics based on categories that include products from both country-of-production sets we wish to compare.[17] We compare the value of $\text{Correl}^{\Delta P_{\text{inter}}}$ between the following pairs of country-of-production sets: (i) US exported products and Canada-ROW exported products, (ii) US exported products and products produced domestically in each country, and (iii) US-Canada-ROW exported products and products produced domestically in each country. Given that this exercise requires a large number of product matches, we use the set of identical plus conservative product matches.

Our findings are as follows. First, exported products have a higher international correlation of price movements relative to domestically produced products (10.7% higher, on average, over the 25 comparable product categories). Second, US exported products have a

[17]In particular, we only include those product categories for which products in each of the two country-of-production sets accounts for at least 5% of total expenditures.

higher international correlation of price movements relative to Canada-ROW exported products (6% on average over the 14 comparable product categories). This suggests seems to suggest that US exporters engage in a higher degree of pricing-to-market than Canada and ROW exporters.[18] These results should be taken with caution, given the small number of categories that have a combination of products from different location-of-production sets.

Note also that Figure 1 shows that, while movements in aggregate RERs are large, there are differences in magnitude across our country-of-production sets. Again, these direct comparisons mix differences between country-of-production sets and differences between product categories. Unfortunately, we do not have sufficient data to compare accurately the magnitude of movements in aggregate RERs across these country-of-production sets.

Relation between product-level and aggregate real-exchange rate movements We now ask the question: do exported goods that display a high degree of idiosyncratic pricing-to-market also display a high degree of pricing-to-market in response to movements in relative unit labor costs? As we show later, our model has a clear prediction regarding this relation.

To address this question, we investigate whether groups of exported products that exhibit a low international correlation of price changes, also experience large aggregate RER movements in response to a change in the relative unit labor costs. We group individual products by their product categories, as defined by the retailer. This approach has the advantage that products within a category share many similar characteristics.

First, we identify product categories with a minimum expenditure share and a minimum number of observations accounted for by exported products (in order to minimize small sample uncertainty for product categories with very few observations).[19] We include both identical and conservative matches to increase the number of observations. We end up with 21 product categories. For each product category j, we then calculate $\text{Correl}_j^{\Delta P^{\text{inter}}}$ and the average quarterly change in the category-wide RER (denoted by ΔQ_j) relative to the change in the relative unit labor cost for the quarters with available information.

Figure 4 displays a scatter plot of $\text{Correl}_j^{\Delta P^{\text{inter}}}$ and ΔQ_j across our 21 product categories

[18] Our findings are consistent with those in Knetter (1990 and 1993). Those papers use information on export unit values to show that pricing-to-market by US exporters is lower than pricing-to-market by exporters from other major industrialized countries.

[19] In particular, we consider products with at least 8 price growth observations in our time period, and product categories with an expenditure share on exported products of at least 5% and a minimum of $1,500$ observations per quarter.

with sufficient information. We observe a negative relation between these two statistics. Indeed, regressing ΔQ_j on a constant and $\text{Correl}^{\Delta P_{\text{inter}}}$ yields a regression coefficient equal to -2.4 with a t-statistic of -2.6 (and hence significant at the 5% level). Our data therefore suggest that product categories with low (high) international correlation of price movements, also exhibit large (small) movements in aggregate RERs in response to a change in relative unit labor costs across countries. This finding should be taken with caution given the small number of product categories meeting the minimum data requirements.

4. Model

We now present a stylized model of international trade, multinational production, and intra- and international pricing that we use to isolate key forces that can rationalize our empirical findings. Our model can generate pricing-to-market by exporters, both in response to idiosyncratic shocks and to aggregate movements in relative unit labor costs. Producers choose to move change relative markups across locations even in the absence of costs of changing prices. The model can reconcile volatile movements in relative price across locations (more so between countries than within countries), and low pass-through of aggregate cost shocks into foreign prices thus generating large movements in aggregate RERs.

In this section we describe the model, and then discuss how the structure of our data can be mapped to the specific assumption of the model. In the following two sections we characterize the model's implications for prices, first analytically and then in a parameterized version of the model.

4.1. Geography

Three countries (indexed by i) produce and trade a continuum of goods subject to frictions in international goods markets. In our quantitative analysis, countries 1, 2, and 3 correspond to the US, Canada, and an aggregate of the rest of the world (ROW), respectively. Countries 1 and 2 each contain two symmetric regions (indexed by $r = A$ and B).

4.2. Preferences

Consumers in country i, region r, value a continuum of varieties (indexed by n) according to the CES aggregator:

$$y_{irt} = \left[\int_0^1 (y_{nirt})^{1-1/\eta} \, dn \right]^{\eta/(\eta-1)}, \ \eta \geq 1. \tag{4.1}$$

Utility maximization leads to standard CES demand functions with an elasticity of demand determined by η.

Each variety is potentially supplied by K distinct producers. The output of each potential producer is valued by the representative consumer according to:

$$y_{nirt} = \sum_{k=1}^{K} a_{knirt} y_{knirt} .$$

We refer to $a_{knirt} > 0$ as the idiosyncratic demand shock for product k, variety n, country i, region r, in period t. Different products within a variety are perfect substitutes (in the sense of having an elasticity of substitution equal to infinity), but have different valuations a_{knirt}. As we show below, the assumption of perfect substitutability across products, while extreme, gives an analytically very tractable account of movements in product-level and aggregate RERs.[20]

With these preferences, consumers in country i, region r choose to purchase the product k with the highest demand/price ratio, a_{knirt}/P_{knirt}, and buy a quantity equal to $y_{nirt} = (P_{knirt}/P_{irt})^{-\eta} y_{irt}$. Here, P_{irt} denotes the price of the consumption composite, and P_{knirt} denotes the price of product k, variety n, country i, region r, in period t.

Idiosyncratic demands shocks are distributed independently across products and time, but are potentially correlated across regions within the same country.[21] In particular, demand shocks for a product in a country are distributed according to:

$$\begin{pmatrix} \log\ a_{kniAt} \\ \log\ a_{kniBt} \end{pmatrix} \sim N\left(0, \begin{pmatrix} \sigma_a^2 & \rho_a\sigma_a^2 \\ \rho_a\sigma_a^2 & \sigma_a^2 \end{pmatrix}\right),$$

where σ_a denotes the standard deviation, and ρ_a the intra-national correlation of demand shocks. We assume that demand shocks are uncorrelated across countries for simplicity. In Appendix 3 we show that our main qualitative results are unchanged if we relax this assumption.

4.3. Technologies

Each variety has K_i potential producers from country $i \in \{1, 2, 3\}$, giving a total of $K = K_1 + K_2 + K_3$ potential producers of each variety in the world. These potential producers

[20] Atkeson and Burstein (2008) study a simpler version of this model in which products within each variety are imperfect substitutes. While this assumption makes the model less analytically tractable, its qualitative implications for pricing are not substantially different than those under the assumption of perfect substitubility.

[21] We include idiosyncratic demand shocks, as opposed to variety-wide demand shocks, because in our data movements in individual product-level RERs are very large relative to category-wide movements in RERs.

of each variety have technologies to produce the same good with different marginal costs. Specifically, each potential producer has a constant returns production technology of the form $y = l/z$, where l is labor and z is the inverse of a productivity realization that is idiosyncratic to that producer.

Firms from countries 1 and 2 can serve the other country either by producing domestically and exporting, or by engaging in multinational production (MP) and producing abroad.[22] Exports are subject to iceberg costs $D \geq 1$.[23] Productivity for multinational production is $1/z'$, where $z'/z \geq 1$ is the producer-specific efficiency loss associated to MP. Firms from country 3 can serve countries 1 and 2 only by producing domestically and exporting (subject to an iceberg cost $D^* \geq 1$ that can be different to D). International trade is costless when $D = D^* = 1$. For simplicity, we abstract from frictions in intra-national goods markets by assuming that producers face equal costs of supplying the two regions within each country. In Appendix 3, we show that our qualitative results are unchanged if we relax this assumption.

We assume that it is technologically unfeasible for any third party to ship goods across regions or countries to arbitrage price differentials. In other words, as suggested by our data, firms can segment markets and charge different prices in each location.[24]

We denote by W_i the wage in country i, expressed in terms of a common numeraire. For a country 1 firm with idiosyncratic productivity $1/z$ and $1/z'$ for domestic and foreign production, respectively, the marginal cost of supplying each country is:

$$\text{Marginal cost for country 1 firms} = \begin{cases} W_1 z \text{ , domestic sales in country 1} \\ DW_1 z \text{ , exports to country 2} \\ W_2 z' \text{ , foreign prod. and foreign sales to country 2} \end{cases}$$

If $z' > z$, a firm faces a nontrivial choice of supplying country 2: it can export its product subject to iceberg costs, or produce abroad subject to a productivity loss. We assume that producers that are indifferent between exporting or engaging in multinational production choose to export.

[22] Neiman (2008) studies a related model of international pricing and compares the implications on exchange-rate pass-through of multinational production and outsourcing.

[23] In our model, international trade costs have identical implications for trade volumes and prices as home bias for national goods built into preferences.

[24] One can show that, under our pricing assumptions, if demand shocks are sufficiently small (i.e. a low value of σ_a), then deviations from the law of one price across countries are limited by the size of trade costs D. In this case, no third party has an incentive, in equilibrium, to ship goods to arbitrage these price differentials across countries.

Similarly, for country 2 firms we have:

$$\text{Marginal cost for country 2 firms } = \begin{cases} W_2 z \text{ , domestic sales in country 2} \\ DW_2 z \text{ , exports to country 1} \\ W_1 z' \text{ , foreign prod. and foreign sales to country 1} \end{cases}$$

Finally, the marginal cost for country 3 firms is:

$$\text{Marginal cost for country 3 firms } = D^* W_3 z \text{ , exports to country 1 or 2}$$

Idiosyncratic marginal cost

We denote the idiosyncratic marginal cost in period t for a firm that produces domestically product k, variety n, by z_{knt}. We assume that z_{knt} is the product of a permanent component, $\bar{z}_{kn}$, and a temporary component, $\tilde{z}_{knt}$:

$$z_{knt} = \bar{z}_{kn} \tilde{z}_{knt}.$$

Analogously, for foreign production:

$$z'_{knt} = \bar{z}'_{kn} \tilde{z}'_{knt}.$$

In order to gain analytical tractability, we make the following two distributional assumptions. First, following Ramondo and Rodriguez-Clare (2008), the permanent component of marginal cost is determined from the draw of two independent random variables:

$$\bar{u} \sim \exp(1) \text{ and } \bar{u}' \sim \exp(\lambda) \ .$$

We then define:

$$\bar{z} = \left(\min\left\{\bar{u}, \bar{u}'\right\}\right)^{\theta}, \text{ and } \bar{z}' = \left(\bar{u}'\right)^{\theta}.$$

A higher value of λ lowers the average draw of $\bar{u}'$, and hence increases the competitiveness of foreign production relative to domestic production. In particular, the probability that $\bar{z}' \geq \bar{z}$, so that producers face a higher productivity of supplying the foreign market via exports, is equal to $1/(1+\lambda)$, which is decreasing in λ.

Second, we assume that the temporary components of marginal cost, $\tilde{z}_{knt}$ and $\tilde{z}'_{knt}$, are drawn independently every period from a lognormal distribution. In particular, the logarithm of $\tilde{z}_{knt}$ and $\tilde{z}'_{knt}$ are normally distributed with mean 0 and standard deviation σ_z.

Aggregate costs

Our approach is partial equilibrium in that we take as given the movements in the cost of labor, W_i. This is without loss of generality for the model's pricing implications, as price changes are independent of the source of the shock that leads to a given change in relative labor costs. Thus, for simplicity, we assume that the logarithm of the wage in each country is drawn every period from a normal variable that is independent over time and countries, with standard deviation σ_w. We do not address in this paper the general equilibrium question of what shocks lead to these large and persistent changes in relative labor costs across countries.

We denote by c_{knirt} the marginal cost of supplying product k, variety n, to country i, region r, in period t, conditional on the optimal choice on exporting or engaging in MP. It is the product of the idiosyncratic marginal cost, the wage, and international trade costs in the case where the product is exported.

4.4. Pricing

Recall that consumers in each region purchase the product with the highest demand/price ratio, a_{knirt}/P_{knirt}. We consider two alternative assumptions on the type of competition that determines prices: perfect competition and Bertrand competition.

Perfect Competition

Under perfect competition, the price of active producers is equal to their marginal cost. Therefore, within each region, the active producer is that with the highest demand/cost ratio a_{knirt}/c_{knirt}. We denote the demand shock and marginal cost of the highest demand/cost producer by a^{1st}_{nirt} and c^{1st}_{nirt}, respectively. The price of variety n in country i, region r, is:

$$P_{nirt} = c^{1st}_{nirt}. \tag{4.2}$$

Bertrand Competition

Under Bertrand competition, each variety is supplied by the product with the highest a_{knirt}/P_{knirt}, as under perfect competition. However, the price charged equals:

$$P_{nirt} = \min\left\{\frac{\eta}{\eta-1}c^{1st}_{nirt}\ ,\ \frac{a^{1st}_{nirt}}{a^{2nd}_{nirt}}c^{2nd}_{nirt}\right\}. \tag{4.3}$$

Here, a^{2nd}_{nirt} and c^{2nd}_{nirt} indicate the demand shock and marginal cost of the "latent competitor", which is the producer with the second highest demand/cost ratio of supplying that variety to the specific country and region. The optimal price is the minimum between (i) the monopoly price and, (ii) the maximum price at which consumers choose the active product when the latent competitor sets its price equal to marginal cost.

4.5. Mapping of Data to Model

While extremely stylized, we view the mapping between our price data and the model as follows. Recall that our retailer classifies individual products into different categories (e.g. "Peanut butter and spreads" and "Pretzels"). In our model, each product category is associated to a CES aggregator like (4.1), and can differ in the values of parameters K, D, D^*, η, etc. Each of the individual products within a product category corresponds in our model to a variety n. Under our assumptions, there is only one active product within each variety. An extension of the model in which goods within a variety are imperfect substitutes (as in Atkeson and Burstein 2008) results in more than one active producer per variety, without changing the qualitative pricing implications of the model while making it significantly less analytically tractable.

Even though products in our dataset are sold to consumers through a retailer, our model abstracts from retail considerations. Extending our model to incorporate a retail sector with constant retail markups and/or distribution margins would not alter its implications on pricing at the wholesale level. This assumption of constant retail markups receives some support by the findings in Eichenbaum, Jaimovich and Rebelo (2008), who show that the retailer in our data does not significantly vary over time its markups over wholesale prices at quarterly frequencies.

In our model, we do not distinguish between producer prices and wholesale prices (as in the models in Goldberg and Hellerstein 2008 and Nakamura 2008). Extending our model to include wholesale margins that are constant over time in percentage terms would not change its pricing predictions. Moreover, in Section 5 we argue that time-varying region- and product-specific wholesale margins would have to be extremely volatile to account for the large relative wholesale price movements in our data.

We focus on the pricing implications of our model for matched products that are sold by the same producer in multiple geographic locations across time periods, as in our data analysis in Section 2. We group matched products into four mutually exclusive country-of-production sets: (i) those that are supplied in all four regions by the same producer located in country 1 (and exported to country 2) in period t, N_{x1t}, (ii) those that are supplied in all regions by the same producer located in country 2 (and exported to country 1) in period t, N_{x2t}, (iii) those that are supplied in all regions by the same producer located in country 3 (and exported to both countries 1 and 2) in period t, N_{x3t}, and (iv) those that are supplied by the same domestic producer in each region in period t, N_{dt}. The set of products N_{dt} includes producers from country 1 that serve country 2 via MP, and producers from country 2 that serve country 1 via MP. Note that many varieties are not matched, but instead are produced by different producers in at least two regions.

For each of these four country-of-production sets, we construct using price data generated from the model, the same statistics that we construct in the data: the variance of price changes, $\text{Var}^{\Delta P}$, the correlation of price changes across regions within and across countries, Correl^{intra} and Correl^{inter}, the variance of relative price changes within and across countries, $\text{Var}^{\text{intra}}$ and $\text{Var}^{\text{inter}}$, and the change in the aggregate RER, ΔQ_t. Given that these statistics are based on price changes, we only use the set of products that are active and belong two the same country-of-production set in two consecutive periods.

5. Model: Analytic Results

In this section, we consider a version of the model with small time-variation of cost, demand, and wage shocks. The small time-variation implies that switching over time in the identity of active producers and latent competitors is arbitrarily small. With this assumption, we can derive simple expressions for our price statistics in terms of the underlying parameters. In Section 6 we relax this assumption and numerically solve for these statistics.

This section is organized as follows. Lemma 1 characterizes the sets of active producers, matched products, and the sets of latent competitors in terms of a subset of the model's parameters. Lemma 2 shows that the fraction of producers facing the same latent competitor in both countries (this ratio is key under Bertrand competition) is decreasing in the extent of international trade costs. Propositions 1 and 2 provide expressions for the movements in product-level and aggregate RERs in terms of the model parameters under Perfect competition (Proposition 1) and Bertrand competition (Proposition 2). We defer various details of the proofs to Appendix 2. We conclude this section by discussing the ability of our model, as well as alternative models, to account for our empirical observations in Section 3.

5.1. Characterizing Active and Latent Producers

We start by characterizing the set of active producers, matched products, and the sets of latent competitors in terms of the model's parameters.

Lemma 1: Consider the limit of our model economy as σ_z, σ_a, and σ_w are positive but arbitrarily close to zero. Then, the following variables can be expressed as simple functions of the model's parameters: (i) the mass of exporters from country i to country j, m_{ij}, (ii) the mass of exporters from country i facing a latent competitor from country l when selling in country j, s_{ij}^{l}, and (iii) the mass of exporters from country i facing the same latent competitor from country l when selling in countries 1 and 2, s_{i}^{l}. These variables depend only on the model's parameters K_1, K_2, K_3, D, θ, and λ. Furthermore, the identity of active and latent producers is the same in both regions within each country.

Proof: As σ_z, σ_a, and σ_w approach zero, $a_{knirt}/\left(z_{knt}W_{it}\right)$ and $a_{knirt}/\left(z'_{knt}W_{it}\right)$ converge in distribution to time-invariant random variables $1/\bar{z}_{kn}$ and $1/\bar{z}'_{kn}$ that are exponentially distributed. This result follows directly from Slutzky's lemma. With m_{ij}, s_{ij}^{1}, and s_{i}^{l} continuos functions of $a_{knirt}/\left(z_{knt}W_{it}\right)$ and $a_{knirt}/\left(z'_{knt}W_{it}\right)$, the limit of m_{ij}, s_{ij}^{1}, and s_{i}^{l} can be evaluated using the convenient properties of exponentially distributed random variables $\bar{z}_{kn}$ and $\bar{z}'_{kn}$, in terms of the parameters K_1, K_2, K_3, D, θ, and λ. In deriving these expressions, we also characterize the sets N_{x1t}, N_{x2t}, N_{x3t}, and N_{dt}. With our assumption that $\bar{z}_{kn}$ and $\bar{z}'_{kn}$ are common to both regions within each country, the identity of active and latent producers in our limit economy is the same in both regions within each country. We present the details of the derivations in Appendix 2. Q.E.D.

Note from Lemma 1 that, in this limit of our model, the identity of active and latent producers is determined only by the permanent component of marginal cost, $\bar{z}_{kn}$, $\bar{z}'_{kn}$, and the level of international trade costs D. Time-varying cost and demand shocks play no role in shaping these patterns. Hence, we can solve our model in two steps. First, we solve for the time-invariant set of active producers, latent competitors, and trade patterns as functions of the parameters K_1, K_2, K_3, D, θ, and λ. Second, we solve for the movements in prices over time for sufficiently small cost and demand shocks.

We now define a variable of the model that is an important determinant of price movements under Bertrand competition. Denote by r_i the fraction of exporters from country i facing the same latent competitor when selling in countries 1 and 2, $r_i = \frac{1}{m_{ij}} \sum_{l=1}^{3} s_{i}^{l}$ for $i = 1, 2$. Lemma 2 states that, in the absence of international trade costs, all exporters face the same latent competitor in countries 1 and 2, $r_i = 1$, and that the extent to which exporters face the same latent competitor in both countries is decreasing in the size of international trade costs.

Lemma 2: In the limit of our model economy as σ_z, σ_a, and σ_w approach zero, r_i is equal to 1 if $D = 1$, and r_i is decreasing in D.

Proof: Recall from Lemma 1 that in this limit of our model, the identity of active and latent producers is determined only by the permanent components of marginal cost. This has the following implications. Exporters from country $i = 1, 2$ facing a latent competitor from their home country i when selling in country j, face the same latent competitor when selling domestically. This is because if two producers from country i are the lowest cost producers of supplying a good in country $j \neq i$, they must also be the lowest cost producers of supplying the home country. Therefore, $s_{12}^1 = s_1^1$ and $s_{21}^2 = s_2^2$. Similarly, exporters from country $i = 1, 2$ facing a foreign latent competitor from country $j = 2, 1$ in the domestic market, face the same foreign latent competitor when selling abroad in country $j = 2, 1$. Therefore, $s_{11}^2 = s_1^2$ and $s_{22}^1 = s_2^1$. Then, r_1 and r_2 can be expressed as:

$$r_i = \left(s_{i,-i}^i + s_{ii}^{-i} + s_i^3\right) / \left(s_{i,-i}^1 + s_{i,-i}^2 + s_{i,-i}^3\right), \tag{5.1}$$

where we used the fact that $m_{ij} = \sum_{l=1}^3 s_{ij}^l$.

With $D = 1$, producers have the same costs for domestic and export sales. Hence, the set of active producers and latent competitors is the same in both countries. This implies that $s_i^l = s_{ii}^l = s_{i,-i}^l$. Therefore, we have

$$r_i = \left(s_{i-i}^i + s_{ii}^{-i} + s_i^3\right) / \left(s_{i,-1}^1 + s_{i,-1}^2 + s_{i,-1}^3\right) = 1,$$

because $s_{ii}^{-i} = s_{i,-1}^{-1}$and $s_i^3 = s_{i,-1}^3$. In Appendix 2, we use our expressions for s_{ij}^l and s_i^l to show that s_{i-i}^i / m_{ij}, s_{ii}^{-i} / m_{ij}, s_i^3 / m_{ij}, and hence r_i are decreasing in D. Q.E.D.

Lemmas 1 and 2 characterize the set of exporters and latent competitors when time variation in demand shocks, cost shocks, and wages is assumed to be very small. We now characterize the behavior of prices in our limit economy with arbitrarily small but positive time-varying shocks, so that we can abstract from switching in the set of exporters and competitors.

5.2. Perfect Competition

We characterize the movements in prices under perfect competition in the following Proposition.

Proposition 1: Consider the limit of our model economy as σ_z, σ_a, and σ_w approach zero but remain positive. The variance of price changes for any set of matched products is

$$\text{Var}^{\Delta P} = 2\left(\sigma_z^2 + \sigma_w^2\right). \tag{5.2}$$

For any set of matched products, the correlation of price changes and the variance of relative price changes across regions in the same country are $\text{Correl}^{\Delta P\text{intra}} = 1$ and $\text{Var}^{\text{intra}} = 0$, respectively. For matched exported products (those in sets N_{x1}, N_{x2}, and N_{x3}), the correlation of price changes and the variance of relative price changes across regions in different countries are $\text{Correl}^{\Delta P\text{inter}} = 1$ and $\text{Var}^{\text{inter}} = 0$, respectively. For matched products in the set N_d, the correlation of price changes and the variance of relative price changes across regions in different countries are $\text{Correl}^{\Delta P\text{inter}} = 0$ and $\text{Var}^{\text{inter}} = 2\text{Var}^{\Delta P}$, respectively.

The change in the aggregate RER in response to a movement in relative wages is $\Delta Q_t = 0$ for exported products, and $\Delta Q_t = \Delta W_{2t} - \Delta W_{1t}$ for matched products that are produced domestically in each country.

Proof: Under perfect competition, prices of active products are set equal to the marginal cost of the lowest cost producer, so the percentage price change of an active product is $\Delta P_{nirt} = \Delta c^{1st}_{nirt}$. The change in marginal cost is equal to the sum of the change in the wage and the temporary component of the active producer's idiosyncratic marginal cost, $\Delta c^{1st}_{nirt} = \Delta W^{1st}_{nirt} + \Delta z^{1st}_{nirt}$. With i.i.d. lognormal shocks, the asymptotic variance of ΔP_{nirt} is (5.2). Given that producers are subject to a common cost shock in supplying both regions in the same country, we have $correl\left(\Delta P_{niAt}, \Delta P_{niBt}\right) = 1$. Exporters are subject to the same marginal cost shock for domestic and foreign sales, so the correlation of price changes across two regions in different countries is $correl\left(\Delta P_{n1At}, \Delta P_{n2At}\right) = 1$. For matched products that are produced domestically in each country, shocks to the temporary component of the firm's idiosyncratic marginal cost and shocks to the wage are independently distributed across countries, so $correl\left(\Delta P_{n1At}, \Delta P_{n2At}\right) = 0$. We then calculate the variance of product-level RERs, $\text{Var}^{intra} = Var\left(\Delta Q_{niiABt}\right)$ and $\text{Var}^{inter} = Var\left(\Delta Q_{n12AAt}\right)$, using expressions (3.2)-(3.3) for the case with two symmetric countries.

Consider now movements in the aggregate RER between two periods of time, constructed as a weighted average of product-level RERs between two countries across a large set of products, as defined in (3.1). For simplicity, we compute this average only over products sold in region A in country 1 and region A in country 2. This is without loss of generality given our assumption that regions within countries are symmetric. For exported products, product-level RERs are constant over time, $\Delta Q_{n12AAt} = 0$. Hence, aggregate RERs are also constant over time, $\Delta Q_t = 0$. For matched products that are produced domestically in each country, $\Delta Q_{n12AAt} = \Delta c^{1st}_{n2At} - \Delta c^{1st}_{n1At} = (\Delta W^{1st}_{n2At} + \Delta z^{1st}_{n2At}) - (\Delta W^{1st}_{n1At} + \Delta z^{1st}_{n1At})$. Given that the mean of $\Delta z^{1st}_{n2At} - \Delta z^{1st}_{n1At}$ over a large number of products is equal to zero, the change in the aggregate RER is $\Delta Q_t = \Delta W_{2t} - \Delta W_{1t}$. Q.E.D.

Under perfect competition, exporters do not engage in pricing-to-market because changes in prices equal changes in marginal costs, and changes in marginal cost are the same irrespective of where the good is sold. In contrast, matched domestically-produced goods display movements in relative prices that reflect movements in marginal costs across locations. The magnitude of these movements is independent of the size of international trade costs.

Note that in an alternative model in which each variety is supplied in the world by one single producer, prices are set at a constant markup over marginal cost. This alternative specification shares the same predictions on fluctuations in international relative prices as our model with perfect competition.

5.3. Bertrand Competition

We now characterize the behavior of prices under Bertrand competition. We assume, for simplicity, that the elasticity of demand η is sufficiently close to one so that the monopoly price is very high and the monopoly price in (4.3) never binds. We summarize our results in the following proposition:

Proposition 2: Consider the limit of our model economy as σ_z, σ_a, and σ_w approach zero but remain positive, and η is close to one. The variance of price changes for any set of matched products is given by:

$$\text{Var}^{\Delta P} = 2\left(2\sigma_a^2 + \sigma_z^2 + \sigma_w^2\right) \tag{5.3}$$

The correlation of price changes across regions in the same country for any set of matched products is

$$\text{Correl}^{\Delta P\text{intra}} = \frac{2\rho_a\sigma_a^2 + \sigma_z^2 + \sigma_w^2}{2\sigma_a^2 + \sigma_z^2 + \sigma_w^2}. \tag{5.4}$$

The correlation of price changes across regions in different countries for matched products in the set N_{xi} is:

$$\text{Correl}^{\Delta P\text{inter}} = \frac{\sigma_z^2 + \sigma_w^2}{2\sigma_a^2 + \sigma_z^2 + \sigma_w^2} r_i. \tag{5.5}$$

The variance of relative price changes across regions in the same country for any set of matched products is

$$\text{Var}^{\text{intra}} = 8\sigma_a^2\left(1 - \rho_a\right) \text{ and} \tag{5.6}$$

The variance of relative price changes across regions in different countries in the set N_{xi} is

$$\text{Var}^{\text{inter}} = 4\left[2\sigma_a^2 + \left(\sigma_z^2 + \sigma_w^2\right)(1 - r_i)\right] \tag{5.7}$$

The change in the aggregate RER in response to a movement in relative wages for matched products in the set N_{xi} is

$$\Delta Q_t = (1 - r_i)\,\Delta\left(W_{2t}/W_{1t}\right) + \frac{1}{m_{i,-i}}\left[\left(s_{i1}^3 - s_i^3\right)\Delta W_{1t} + \left(s_i^3 - s_{i2}^3\right)\Delta W_{2t} + \left(s_{i2}^3 - s_{i1}^3\right)\Delta W_{3t}\right]. \tag{5.8}$$

Proof: Under Bertrand competition, prices of active products are given by (4.3). With η is sufficiently close to one, the limit price $a_{nirt}^{1st}/a_{nirt}^{2nd} * c_{nirt}^{2nd}$ is always binding. Hence, changes in prices of active products are given by:

$$\Delta P_{nirt} = \Delta a_{nirt}^{1st} - \Delta a_{nirt}^{2nd} + \Delta c_{nirt}^{2nd}. \tag{5.9}$$

With iid lognormal cost and demand shocks, the asymptotic variance of ΔP_{nirt} is (5.3).

Consider now the correlation of price changes across two regions in the same country:

$$correl\left(\Delta P_{niAt}, \Delta P_{niBt}\right) = cov\left(\Delta c_{niAt}^{2nd} + \Delta a_{niAt}^{1st} - \Delta a_{niAt}^{2nd}, \Delta c_{niBt}^{2nd} + \Delta a_{niBt}^{1st} - \Delta a_{niBt}^{2nd}\right)/\text{Var}^{\Delta P}. \tag{5.10}$$

From Lemma 1, active producers face the same latent competitor in both regions within the same country, so $\Delta c_{niAt}^{2nd} = \Delta c_{niBt}^{2nd}$, and $cov\left(\Delta c_{niAt}^{2nd}, \Delta c_{niBt}^{2nd}\right) = 2\left(\sigma_z^2 + \sigma_w^2\right)$. On the other hand, $cov\left(\Delta a_{niAt}^{1st} - \Delta a_{niAt}^{2nd}, \Delta a_{niBt}^{1st} - \Delta a_{niBt}^{2nd}\right) = 4\sigma_a^2 \rho_a$. Plugging-in these results into (5.10), and using (5.3), we obtain (5.4).

Consider now the correlation of price changes across region A, country 1 and region A, country 2:

$$correl\left(\Delta P_{n1At}, \Delta P_{n2At}\right) = cov\left(\Delta c_{n1At}^{2nd} + \Delta a_{n1At}^{1st} - \Delta a_{n1At}^{2nd}, \Delta c_{n1At}^{2nd} + \Delta a_{n1At}^{1st} - \Delta a_{n1At}^{2nd}\right)/\text{Var}^{\Delta P}. \tag{5.11}$$

With our assumption that demand shocks are uncorrelated across countries, we need only focus on $cov\left(\Delta c_{n1At}^{2nd}, \Delta c_{n2At}^{2nd}\right)$. For producers facing the same latent competitor in both countries (a fraction r of all the matched products), $\Delta c_{n1At}^{2nd} = \Delta c_{n2At}^{2nd}$, so $cov\left(\Delta c_{n1At}^{2nd}, \Delta c_{n2At}^{2nd}\right) = 2\left(\sigma_z^2 + \sigma_w^2\right)$. For producers facing a different latent competitor in each country (a fraction $1 - r$ of all the matched products), $\Delta c_{n1At}^{2nd} \neq \Delta c_{n2At}^{2nd}$, and with iid lognormal shocks, $cov\left(\Delta c_{n1At}^{2nd}, \Delta c_{n2At}^{2nd}\right) = 0$. Plugging-in these results into (5.11), and using (5.3), we obtain (5.5). We can then calculate the variance of product-level RERs, $\text{Var}^{intra} = Var\left(\Delta Q_{niiABt}\right)$

and $\text{Var}^{inter} = Var\left(\Delta Q_{n12AAt}\right)$ using expressions (3.2)-(3.3) for the case with two symmetric countries.

Consider now the change in the aggregate RERs across two periods. For matched exported products in the set N_{xi}, we have

$$\begin{aligned}\Delta Q_t &= \int_{N_{xi}} \psi_{n21AAt-1}\Delta Q_{n21AAt}\mathrm{d}n \qquad (5.12)\\ &= \int_{N_{xi}} \psi_{n21AAt-1}\left[\left(\Delta a_{n2At}^{1st} - \Delta a_{n2At}^{2nd} + \Delta c_{n2At}^{2nd}\right) - \left(\Delta a_{n1At}^{1st} - \Delta a_{n1At}^{2nd} + \Delta c_{n1At}^{2nd}\right)\right]\mathrm{d}n\\ &= \int_{N_{xi}} \psi_{n21AAt-1}\left(\Delta W_{n2At}^{2nd} - \Delta W_{n1At}^{2nd}\right)\mathrm{d}n\\ &= \frac{1}{m_{i,-i}}\left[\left(s_{i2}^{1} - s_{i1}^{1}\right)\Delta W_{1t} + \left(s_{i2}^{2} - s_{i1}^{2}\right)\Delta W_{2t} + \left(s_{i2}^{3} - s_{i1}^{3}\right)\Delta W_{3t}\right]\ ,\end{aligned}$$

where s_{ij}^{l} and $m_{i,-i}$ are defined in Lemma 1, and $\psi_{n21AAt-1}$ is the average share of product n in total expenditures in countries 1 and 2, region A, over the products in set N_{xi}. The second line in (5.12) is derived using (5.9). The third line is derived using the assumption that the mean of Δa and Δz over a large number of products is equal to zero, which implies that on average the change in the marginal cost of the latent competitor in country i, region r, is equal to the change in the wage of the latent competitor in this location, W_{n2At}^{2nd}. The fourth line in (5.12) uses notation introduced in Lemma 1 for the fraction of exporters from country i facing a latent competitor from country l when selling in country j, $s_{ij}^{l}/m_{i,i}$, and the result that with η close to 1, the measure of products in any given set is equal to the expenditure share on these products. Finally, using $m_{ij} = \sum_{l=1}^{3} s_{ij}^{l}$ and the definition of r_i, we obtain (5.8). Q.E.D.

Expression (5.5) displays the correlation of price changes across regions in different countries for exported products. This expression can be understood as follows. Suppose first that price changes are driven only by cost shocks ($\sigma_a = 0$). Exporters facing the same latent competitor in both countries set prices that are perfectly correlated across countries (i.e. they do not engage in pricing-to-market) because the latent competitor is hit by the same cost shock in both countries. In contrast, exporters facing a different latent competitor in each country set prices that are uncorrelated across countries (i.e. they do engage in pricing-to-market) because the cost shocks to each latent competitor are uncorrelated. Hence, $\text{Correl}^{\Delta P\text{inter}} = 0 * (1 - r) + 1 * r$.

Suppose instead that price movements are driven solely by demand shocks. Given that these shocks are uncorrelated across countries, exporters set prices changes that are uncorrelated across countries (i.e. $\text{Correl}^{\Delta P^{\text{inter}}} = 0$).

With both cost and demand shocks, the correlation of price changes is a weighted average between r and 0, with a weight to the prior determined by the importance of cost shocks in the variance of price changes, $(\sigma_z^2 + \sigma_w^2) / (2\sigma_a^2 + \sigma_z^2 + \sigma_w^2)$.

In calculating the correlation of price changes across regions within the same country, we need to take into account that all producers face the same latent competitor in both regions, and that demand shocks are correlated across regions. Using a similar logic as before, we obtain (5.4). Note that pricing-to-market across regions in the same country is more prevalent if demand shocks are not highly correlated across regions.

Combining (5.6) and (5.7), we obtain a simple expression that summarizes the extent to which pricing-to-market is more extensive across countries than within countries:

$$\frac{\text{Var}^{\text{inter}}}{\text{Var}^{\text{intra}}} = \frac{1 + \frac{\left(\sigma_z^2+\sigma_w^2\right)}{2\sigma_a^2}\left(1 - r_i\right)}{1 - \rho_a} \tag{5.13}$$

A high inter/intra-national ratio of RER variances for exporters can result from (i) a low fraction of exporters facing the same latent competitor in both countries, (ii) a high contribution of cost shocks in overall price fluctuations, and (iii) a high correlation of demand shocks within countries.

To understand better the movements in relative prices resulting from an aggregate change in relative labor costs across countries, displayed in expression (5.8), suppose that international trade costs from countries 1 and 2 to the rest of the world, D^*, are very high. Then, it is very unlikely that producers selling in countries 1 and 2 face a country 3 latent competitor ($s_{i1}^3 \simeq 0$) and the change in the aggregate RER is:

$$\Delta Q_t = (1 - r_i)\, \Delta \left(W_{2t}/W_{1t}\right) \tag{5.14}$$

This expression indicates that aggregate RERs are more responsive to movements in relative wages (i.e. there is more pricing-to-market) the lower the fraction of producers facing the same latent competitor in both countries (i.e.: low r_i). This is because a low r_i indicates that exporters are likely to face local latent competitors in each country, implying that prices are more responsive to the local wage in the destination country. In the extreme, with costless international trade ($D = 1$), we have $r_i = 1$ and $\Delta Q_t = 0$ because firms face the same latent competitor in both countries with a common wage change.

Consider now the general case with $s_{i1}^3 > 0$. Suppose that the wages in countries 2 and 3 increase by the same magnitude (i.e. $\Delta W_{3t} = \Delta W_{2t}$). Then, the change in the aggregate

RER is:

$$\Delta Q_t = \left(1 - r_i + \frac{s_i^3 - s_{i1}^3}{m_{i,-i}}\right) \Delta \left(W_{2t}/W_{1t}\right) \tag{5.15}$$

Note that, with $\left(s_i^3 - s_{i1}^3\right)/m_{i,-i} \leq 0$, the movement in the aggregate RER is smaller than that in (5.14). To understand this, recall that $\left(s_{i1}^3 - s_i^3\right)$ indicates the mass of country i exporters facing a latent competitor from country 3 in country 1 and a local latent competitor in country 2. Even though these exporters face different latent competitors in each country, their relative wage remains unchanged. Therefore, in response to the change in W_2/W_1, these exporters do not change the relative price at which they sell their output in the two countries. Our quantitative analysis suggests that this term is relatively small.

In Appendix 3, we extend the results of Proposition 2 in a version of our model in which demand shocks for each product are correlated across countries, producers face different productivity shocks in each region within a country, and can trade goods within countries subject to an intra-national trade cost.

5.4. Discussion

In Propositions 1 and 2, we derived the implications of our model on price movements under two alternative assumptions: perfect competition (or constant markups), and Bertrand competition. We now assess the ability of the models to account for our empirical observations in Section 3. Here, we also discuss the role of international trade costs in shaping our price statistics.

Our data reveal that product-level price movements for matched products are highly correlated across regions within countries, and roughly uncorrelated across regions in different countries. The counterpart of this observation is that product-level RERs are more volatile across countries than within countries, implying large deviations from relative PPP. These patterns hold both for matched products that are exported, and for matched products that are domestically produced in each country. The perfect competition model with time-variation in costs is consistent with the data in predicting that product-level RERs should fluctuate across countries for matched products that are produced domestically in each country. However, this model sharply contrasts with our finding that the product-level RERs for traded products are also volatile; as discussed previously, this observation points to models of pricing-to-market in which exporters systematically raise markups in Canada relative to the US. This observation however is consistent with the Bertrand model, as this model, with time variation in costs and demand, naturally results in the practice of pricing-to-market. Furthermore, the Bertrand model predicts that international movements of RERs should be larger than intra-national movements of RERs if idiosyncratic shocks (cost and demand) are more correlated within than across countries, and if producers are less likely to compete with the same latent competitor across countries than within countries.[25]

Our data also show large swings in aggregate RERs for matched products in response to movements in relative costs across countries. This pattern holds for matched products that are actually traded, as well as for matched products that are produced domestically in each country. The model with perfect competition is consistent with the data in predicting that aggregate RERs should move for matched domestically-produced products. However, it is inconsistent with the data in predicting that aggregate RERs should remain constant for matched traded products. On the other hand, the Bertrand model is consistent with the data in predicting that aggregate RERs should move with changes in relative costs across countries for matched traded products, as long as exporters compete with local latent producers in each country.

The Bertrand model also predicts a negative relation between the international correlation of price changes, $\text{Correl}^{\Delta P_{\text{inter}}}$, and the magnitude of movements in aggregate RERs, ΔQ. Ceteris-paribus, the smaller the fraction of exporters facing the same latent competitor in both countries (i.e.: low r), the lower is $\text{Correl}^{\Delta P_{\text{inter}}}$ and the higher is ΔQ. This negative relation is supported by our data in Section 3 when we compare $\text{Correl}^{\Delta P_{\text{inter}}}$ and ΔQ across various product categories.[26]

Alternative models in which international market segmentation plays a minor role in pricing and prices move only in response to region-specific demand shocks, can also reconcile

[25] Our model with $D > 1$, both under Perfect and Bertrand competition, is also consistent with the findings in Gopinath, Gourinchas, and Hsieh (2008) in predicting that international dispersion in price levels is higher than intranational dispersion in price levels. Our model can be extended to allow for constant region/variety-specific cost differences that equally affect all K potential suppliers within that variety in that region. We can show that the magnitude of these cost differences can be chosen to match any level of inter-to-intra dispersion in price levels, without changing any of our model's implications on price movements.

[26] An alternative way of gauging the central mechanism of the model is to obtain direct measures of the extent to which exporters face local competitors in each country, and to relate these to observed movements in RERs. Constructing these measures requires taking a stand on the relevant scope of competition for each product, including other product categories within the retailer, other retailers, and local producers outside of the retail industry. For example, the relevant set of competitors for Myojo instant noodles includes other Asian noodles, other types of pasta, general food (all of these within and across retailers), as well as Asian or other general restaurants and food suppliers in the geographic region. Our procedure of comparing movements in product-level and aggregate RERs to assess the role of the border has the advantage that it circumvents this difficult measurement problem.

the patterns of intra- and international correlations of price changes if these shocks are more correlated within than across countries. However, such models do not generate large movements of aggregate RERs for traded goods in response to movements in relative labor costs, and they do not have sharp predictions on the relation between $\text{Correl}^{\Delta P^{\text{inter}}}$ and ΔQ. Models that feature shocks to wholesale distribution costs that are region- and product-specific can also partly account for our price observations. However, if wholesale distribution costs account for a modest share of wholesale prices (16% for US nondurable goods as reported in Burstein, Neves, and Rebelo 2003), these shocks would have to be extremely large to account for the large volatility of relative prices documented in Section 3.[27] Finally, models with sticky prices in local currency can generate large movements in aggregate RERs in response to changes in unit labor costs. However, nominal prices in our data change quite frequently and by large magnitudes.

We now discuss the role of the international border, parameterized by D, in shaping our pricing results. In our model, higher international trade costs reduce the volume of international trade, as well as the fraction of exporters facing the same latent competitor in both countries. Therefore, everything else being equal, a higher level of D lowers the international correlation of price changes for exported products, increases the ratio of inter/intra-national volatility of product-level RERs, and increases the movements of aggregate RERs for matched traded products in response to a change in relative costs across countries.

Do differences in the volatility of intra- and international product-level RERs offer sufficient information for assessing the role of international trade costs? No. A high ratio $\text{Var}^{\text{inter}}/\text{Var}^{\text{intra}}$ can result either from high international trade costs, or from cost and demand shocks that are more correlated within countries than across countries.[28][29]

[27] Note that an increase in international trade costs (due to, for example, an increase in the price of fuel) in a model with constant markups would lead to an increase in the price of exports relative to domestic sales. Hence, it cannot account for the fact that in our data, prices in Canada rise relative to prices in the US not only for US exporters, but also for Canadian and ROW exporters.

[28] These implications of our model are closely related to Gorodnichenko and Tesar (2008). They show that differences in intra-and-international RER movements can result from country differences in intra-national RER movements. We extend this result and show that, even with symmetric countries, international RER movements can exceed intra-national RER movements if product-level shocks are more correlated within than across countries.

[29] Our model abstract from other forces that can make pricing-to-market more prevalent across than within countries. For example, wholesalers might engage in more price-discrimination across retail branches belonging to a common retail chain and located in two different countries, than across retail branches located in the same country. See Nakamura 2008 for a discussion of retail pricing of common products across different retail chains.

Finally, our analysis also suggests that data on product-level and aggregate RER fluctuations for matched products produced domestically in each country are not informative enough to gauge the extent of pricing-to-market and international trade costs. This is because, in order to account for these data, we cannot discriminate between our model with variable markups, and a model with perfect competition in which producers engaged in MP are hit by different cost shocks in both countries. In such a model, conditional on the producers' choice of serving the foreign market via exports or MP, trade costs have no bearing on the size of price changes.

6. Model: Quantitative Results

In this section we ask whether our model, when parameterized to match key observations on the volume of trade and intra-national movements of prices in US and Canada, can account quantitatively for the observations on product-level and aggregate real exchange rates presented in Section 3. Since our analytic results show that the model with perfect competition is unable to replicate many basic features of our pricing data, we report only our findings under Bertrand competition.

Model parameterization

We refer to countries 1, 2, and 3 as the US, Canada, and ROW, respectively. The parameters of our model include the elasticity of substitution across varieties, η, the number of potential producers per variety from each country (K_1, K_2, and K_3), the dispersion across producers in the permanent component of productivity, θ, the international trade cost between countries 1 and 2, D, and between these two countries and country 3, D^*, the average productivity loss in multinational production, determined by λ, the volatility of temporary demand and cost shocks, σ_a and σ_z, the intra-national correlation of demand shocks across regions within country, ρ_a, and the movement of wages in each country.

Based on our analysis in Section 4, these parameters can be divided broadly into two groups. First, θ, K_1, K_2, K_3, D, D^*, and λ determine the shares of international trade and multinational production in each country, through the expressions presented in Appendix 2. The parameter θ affects these shares only through D^θ and $(D^*)^\theta$, and K_3 affects those shares only through $K_3/(D^*)^\theta$. These parameters also determine the measures of latent competitors in each country. Second, the parameters η, σ_z, σ_a, ρ_a, and the movement of wages in each country determine how prices change over time. Recall that in deriving these analytical results, we assumed that θ is large relative to σ_z, σ_a, and wage movements, in order to abstract from switching in the identity of active producers and latent competitors. We also assumed that η is close to one so that the monopoly price is not binding.

We choose the values of these parameters to target some key features of expenditure shares and prices of the typical product category in our data. In particular, we set K_2, $K_3/(D^*)^\theta$, $(D)^\theta$, and λ to match the following four observations: (i) the US expenditure share of imports from Canada is 2%, (ii) the Canadian expenditure share of imports from the US is 25%, (iii) the average expenditure share in the US and Canada of imports from the rest of the world is 10%,[30] and (iv) the ratio of Canadian expenditures in matched traded products relative to expenditures in matched products that are produced domestically in each country is 1. Observations (i)-(iii) correspond roughly to the average import shares in gross output between 1997 and 2002 in chemical products, food products, beverages, and tobacco reported by Source OECD.[31] These values are quite close to the import shares for our sample of products (identical and conservative matches) displayed in Table 1. Observation (iv) roughly corresponds to the median ratio of expenditure in traded and domestically-produced matched products across the product categories in the data which contain both of these type of products. We set $K_1 = 28$, which implies that the calibrated value of K_2 is equal to 4. We experimented with higher and lower values of K_1.[32] Conditional on matching our targets, our results remain roughly unchanged. We set $\theta = 0.3$, which is at the high range of values considered in Eaton and Kortum (2002). Recall that θ determines the switching of producers and latent competitors when time-varying shocks are large. For robustness, we also report our findings when $\theta = 0.2$ and $\theta = 0.45$.

We assume that one period in our model corresponds to one quarter. We set σ_z and σ_a to match the magnitude of product-level price movements and intra-national correlation of price changes for US exporters across all product categories in our baseline statistics. In particular, we target $\text{Var}^{\Delta P} = 0.08^2$ and $\text{Correl}^{\Delta P \text{intra}} = 0.75$, which are roughly equal to the average values in Canada and the US. In our baseline calibration, we assume that demand shocks are uncorrelated across regions ($\rho_a = 0$). We also report our findings when ρ_a is chosen to target the international correlation of price movements for US exporters observed

[30]In order to match separately the import share from the ROW in US and Canada, we would need to include in our model a different trade cost for US and Canada with the ROW.

[31]Note that, with balanced trade in each country, import shares in gross output equal to import shares in absorption.

[32]We require $K_1 \geq 14$ in order to be able to match our targets with $K_2 \geq 2$.

in our data, $\text{Correl}^{\Delta P_{\text{inter}}} = 0.1$, conditional on matching the other targets. Our baseline calibration assumes $\eta = 1.01$, as in our analytical approximation. In spite of the low value of η, the model implies an average average markup of 30% because many producers charge the limit price determined by demand and marginal cost of the latent competitor.[33] For robustness, we also report our findings when $\eta = 2$. Table 4 summarizes the parameter values and targets of our baseline parameterization.

We simulate our model for 12 quarters. Initial wages are normalized to one (and trade shares are calibrated at these wage levels). We assume that W_1 remains constant, and that wages in Canada and ROW (expressed in a common numeraire), increase proportionally to the appreciation of the Canadian/US relative unit labor cost in the period 2004-2006. This aggregate experiment resembles the recent global depreciation of the US dollar. To check the accuracy of our analytical approximation, we also report our findings when time-varying shocks are very small, i.e. $\text{Var}^{\Delta P} \simeq 0$ and $\Delta W_2 = \Delta W_3 \simeq 0$.

Pricing implications: Baseline parameterization

Column 1 in Table 5 reports our pricing findings when demand shocks are uncorrelated across regions ($\rho_a = 0$). Recall that the only statistic targeted in our calibration procedure is the intra-national correlation of price changes, $\text{Correl}^{\Delta P_{\text{intra}}}$, for US exporters (equal to 0.75). The three main quantitative findings are as follows.

First, the model implies an international correlation of price changes, $\text{Correl}^{\Delta P_{\text{inter}}}$, for US exporters (equal to 0.26) that is significantly lower than $\text{Correl}^{\Delta P_{\text{intra}}}$. This is due to the presence of international trade costs that segment the extent to which producers face the same latent competitor in different countries. The ratio of inter-to-intra-national standard deviation of product-level RERs is 1.7.

Note, however, that the model's $\text{Correl}^{\Delta P_{\text{inter}}}$ for US exporters is larger than the one observed in our data (equal to 0.1). In order to lower $\text{Correl}^{\Delta P_{\text{inter}}}$ while keeping a constant $\text{Correl}^{\Delta P_{\text{intra}}}$ and $\text{Var}^{\Delta P}$, we can raise the correlation of demand shocks within countries, ρ_a, and increase the size of demand shocks relative to cost shocks, as suggested by expressions (5.3), (5.4), and (5.5). The results under this alternative parameterization are reported in Column 2, Table 5. Note that the ratio of inter-to-intra-national standard deviations of RERs increases to 1.9 when we raise ρ_a. This illustrates our finding that this ratio is

[33] The model also implies that exporters have a higher markup than non-exporters. Given that value-added per worker is proportional to the markup, the model is consistent with the productivity premium of exporters relative to non-exporters observed in US plant level data (see Bernard, et. al. 2003).

determined not only by the size of international trade costs, but also by the extent to which demand shocks are more correlated within than across countries.

Second, the model also generates differences between $\text{Correl}^{\Delta P\text{inter}}$ and $\text{Correl}^{\Delta P\text{intra}}$ (and hence also high ratios of inter/intra-national volatilities of product-level RERs) for matched products exported by Canadian and ROW producers, and also for matched products that are produced domestically in each country. In fact, consistent with our data, $\text{Correl}^{\Delta P\text{inter}}$ is the highest for US exported matched products. This is because, in our model, US exporters engage in less pricing-to-market than do exporters from Canada and ROW. This asymmetry is driven by the relatively high number of US potential producers K_1, which implies that US producers are more likely to export and, conditional on exporting, are more likely to compete with the same US latent producer in both countries. In contrast, if $K_1 = K_2 = K_3$ and $D = D^*$, the model would imply that $\text{Correl}^{\Delta P\text{inter}}$ is equal for all matched exported products.

Third, the model generates large movements in aggregate RERs for matched products in response to movements in aggregate costs across countries. Figure 5 displays the cumulative change in relative unit labor costs W_2/W_1, and the cumulative changes in aggregate RERs, ΔQ, for each set of matched products. Panel B in Table 5 reports the ratio of the cumulative changes in RER to the cumulative change in relative wages. Recall that this ratio is equal to zero under Perfect competition. We find that the model with Bertrand competition generates large movements in aggregate RERs for all sets of matched products. For US exporters, the ratio of RER movements to relative wage movements is 0.64 (in our data this ratio is about 0.85).[34] Moreover, non-US exported matched products display larger movements in aggregate RERs than do US exported products. This asymmetry is driven by the fact that $K_1 > K_2$ and $K_1 > K_3$, which implies that US exporters are more likely to face the same US latent competitor in both countries.

We conclude that our baseline parameterization can, to a large extent, reproduce the major features of product-level and aggregate RERs documented in Section 3.

Pricing implications: Sensitivity Analysis

We now examine the sensitivity of our results to alternative targets and parameter values. We adjust the remaining parameters to match the unchanged targets. The findings are presented in Table 6. Column 1 reports results under our baseline parameterization with

[34] If we introduced local distribution costs at the wholesale level, this ratio would increase and be closer to the level observed in our data. These results are available upon request.

$\rho_a = 0$.

Column 2 reports the results when time-varying shocks are very small. That is, we target $\text{Var}^{\Delta P} \simeq 0$ and $\Delta W_2 = \Delta W_3 \simeq 0$ in our calibration. The results correspond to those using the expressions from our analytical approximation in Section 5.2. For example, $\text{Correl}^{\Delta P\text{inter}} = 0.21$ for US exporters is the product of $r_1 = 0.28$ (i.e. the fraction of US exporters facing the same latent competitor in both countries), and $(\sigma_z^2 + \sigma_w^2) / (2\sigma_a^2 + \sigma_z^2 + \sigma_w^2) = 0.75$ (i.e., the importance of cost shocks in price movements). On the other hand, for Canadian exporters we have $r_2 = 0.185$, leading to $\text{Correl}^{\Delta P\text{inter}} = 0.14$.

Relative to our baseline with large shocks, this alternative parameterization generates a slightly lower $\text{Correl}^{\Delta P\text{inter}}$ (0.21 versus 0.26, for US exporters) and larger movements in aggregate RER for matched products (0.71 vs. 0.64, for US exporters). To understand these differences, recall that small time-varying shocks reduce the extent of switching of exporters and latent competitors over time. Switchers are more likely to compete with foreign producers (i.e., they switch because the cost of the latent competitor changes with the wage movements). If they hadn't switched, they would likely have changed their relative price across countries. By eliminating switchers from our price statistics in the face of large time-varying shocks, we are reducing the extent of relative price movements for matched products.

Column 3 reports our results when we target a lower level of $\text{Correl}^{\Delta P\text{intra}}$. We target a correlation equal to 0.55, instead of our baseline level of 0.75. This alternative parameterization requires demand shocks that are more important in overall price movements, hence reducing $\text{Correl}^{\Delta P\text{inter}}$ from 0.26 to 0.19 for US exporters. Note that our aggregate RER statistics remain roughly unchanged.

Column 4 reports our results if we reduce the competitiveness of multinational production by lowering λ from 0.35 to 0.15. This increases the ratio of expenditures in matched exports to matched domestically-produced goods from 1 to 2. Ceteris-paribus, a lower level of λ increases the volume of international trade and the fraction of exporters facing the same latent competitor in both countries, leading to smaller product-level and aggregate RERs. However, in order to match the shares of trade in the data, trade costs must be reduced, lowering the fraction of exporters facing the same latent competitor in both countries. These two offsetting effects imply that our results remain basically unchanged.

Columns 5 and 6 report our results if we consider a higher and lower dispersion of permanent costs across products, parameterized by θ. The results, while remaining very similar, show that the accuracy of our analytical approximation deteriorates as we lower θ. To see this, note that the analytical results in column 2 are closer to those in Column 5 than Column 4. This is because a higher level of θ increases the role of permanent differences in costs for determining the identity of exporters and latent competitors, and reduces the extent of switching in response to time-varying shocks.

Finally, Column 7 reports our findings when we increase the elasticity of substitution across varieties from $\eta = 1.01$ to $\eta = 2$. Relative to our baseline parameterization, $\text{Correl}^{\Delta P_{\text{inter}}}$ increases slightly for US exporters (from 0.26 to 0.32), and remains roughly unchanged for Canadian exporters. Aggregate movements in RERs fall as a fraction of relative wage movements (from 0.64 to 0.53 for US exporters, and from 0.75 to 0.69 for Canadian exporters). To understand these differences, note that with a higher level of η, the optimal monopoly price becomes more binding in (4.3), and this reduces the extent of variable markups in pricing decisions. Note, however, that movements in product-level and aggregate RERs are still substantial.

7. Conclusions

In this paper, we provide new observations on aggregate and product-level RERs using non-durable goods' price data from a Canada-US retailer, distinguishing between goods that are produced in one country and exported to others, and goods that are produced locally in each country. While the data is limited to one particular retailer and a narrow set of product categories, it provides detailed price information at the level of matched individual products and locations in two countries. Our data reveals large deviations from relative PPP for traded goods and substantial regional pricing-to-market, particularly across countries. To help rationalize our observations, we construct a simple model of pricing-to-market and international trade. The international border plays an important role in our model by segmenting competitors across countries, leading to the practice of pricing-to-market by exporters in response to idiosyncratic shocks and changes in relative labor costs.

We have kept our model highly stylized in order to gain analytical tractability and identify key forces to account for movements in product-level and aggregate RERs. In doing so, we have abstracted from important industrial organization considerations such as richer demand systems, multi-product pricing, interactions between retailers and wholesalers, and long-term relations between producers and retailers. Incorporating these elements into our analysis is an important task for future research. Goldberg and Hellerstein (2008) and Nakamura (2008) are important examples of recent models of incomplete pass-through with richer considerations of industrial organizations.

In our model with variable markups, movements in international relative prices for traded goods are not efficient because they do not move one-to-one with relative costs. The extent of these relative price movements is determined by the magnitude of international border costs and changes in relative unit labor costs, which are themselves shaped by international trade policies and exchange-rate policies. Our framework can be used to study the optimal design of these policies taking into account their effects on welfare from movements in international relative prices for traded goods.

REFERENCES

Alessandria, George. 2004. "International Deviations from the Law of one Price: The Role of Search Frictions and Market Share." *International Economic Review*, 45(4): 1263-1291.

Atkeson, Andrew and Ariel Burstein. 2007. "Pricing-to-Market in a Ricardian Model of International Trade." *American Economic Review*, 97(2): 362-367.

Atkeson, Andrew and Ariel Burstein. 2008. "Pricing-to-Market, Trade Costs, and International Relative Prices" *American Economic Review*, 98(5): 1998-2031.

Bergin, Paul, and Robert Feenstra. 2001. "Pricing-to-market, Staggered Prices, and Real Exchange Rate Persistence." *Journal of International Economics*, 54(2):333-359.

Bernard, Andrew, Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum. 2003. "Plants and Productivity in International Trade." *American Economic Review*, 93(4): 1268-1290.

Broda, Christian, and David Weinstein. 2007. "Understanding International Price Differences using Barcode Data." Mimeo. Univesity of Chicago.

Bils, Mark, and Pete Klenow. 2004. "Some Evidence on the Importance of Sticky Prices," *Journal of Political Economy,* 112, 947-985.

Burstein, Ariel, Joao Neves, and Sergio Rebelo. 2002. "Distribution Costs and Real Exchange Rate Dynamics During Exchange-Rate-Based Stabilizations." *Journal of Monetary Economics*, 50(6): 1189-1214.

Chetty, Raj, Adam Looney and Kory Kroft. 2008. "Salience and Taxation: Theory and Evidence." forthcoming *American Economic Review.*

Corsetti, Giancarlo and Luca Dedola. 2005. "Macroeconomics of International Price Discrimination." *Journal of International Economics*, 67(1): 129-155.

Crucini, Mario, Chris I. Telmer, and Marios Zachariadis. 2005. "Understanding European Real Exchange Rates," *American Economic Review*, 95(3): 724-738.

Crucini, Mario and Mototsugu Shintani. 2008. "Persistence in law of one price deviations: Evidence from micro-data," *Journal of Monetary Economics*, 55(3): 629-644.

Crucini, Mario and Chris Telmer. 2007. "Microeconomic Sources of Real Exchange Rate Variability." Mimeo. Federal Reserve Bank of New York.

Dornbusch, Rudiger. 1987. "Exchange Rates and Prices." *American Economic Review*, 77(1): 93-106.

Drozd, Lukasz, and Jaromin Nosal. 2008. "Understanding International Prices: Customers as Capital." Mimeo. University of Wisconsin.

Eaton, Jonathan and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica.* 70(5): 1741-1779.

Eiran, Liran, Ephraim Leibtag and Aviv Nevo. 2008. **"**Not-so-classical Measurement Errors: A Validation Study of Homescan." Stanford University.

Eichenbaum, Martin, Nir Jaimovich and Sergio Rebelo. 2008. "Reference Prices and Nominal Rigidities." Mimeo. Stanford University.

Engel, Charles. 1999. "Accounting for US Real Exchange Rate Changes." *Journal of Political Economy*, 107(3): 507-538.

Engel, Charles and John Rogers. 1996. "How Wide Is the Border?" *American Economic Review*, 86(5): 1112-25.

Fitzgerald, Doireann and Stefanie Heller. 2008. "Exchange Rates and Producer Prices: Evidence from Micro-Data." Mimeo. Stanford University.

Goldberg, Pinelopi K., and Michael Knetter. 1997. "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature*, 35(3): 1243-1272.

Goldberg, Pinelopi K., and Rebecca Hellerstein. 2006. "A Framework for Identifying the Sources of Local Currency Price Stability with an Empirical Application." Working paper. Federal Reserve Bank of New York.

Gopinath, Gita, and Oleg Itskhoki. 2008. "Frequency of Price Adjustment and Pass-through." Mimeo. Harvard University.

Gopinath, Gita and Roberto Rigobon. 2008. "Sticky Borders" *Quarterly Journal of Economics*, 123(2): 531-575.

Gopinath, Gita, Pierre-Olivier Gourinchas, and Chang-Tai Hsieh. 2008. "Cross-Border Prices, Costs and Mark-ups." Mimeo. National Bureau of Economic Research

Gorodnichenko, Yuriy, and Linda Tesar. 2008. "Border effect or country effect? Seattle may not be so far from Vancouver after all". Working Paper. University of Michigan.

Kehoe, Patrick, and Virgiliu Midrigan. 2008. "Sticky Prices and Real Exchange Rates in the Cross-Section." Mimeo. New York University.

Klenow, Pete, and Olexei Kryvtsov. 2008. "State-Dependent or Time-Dependent Pricing: Does It Matter for Recent U.S. Inflation?" *Quarterly Journal of Economics,* 123: 863:904.

Knetter, Michael. 1989. "Price Discrimination by US and German Exporters." *American Economic Review*, 79(1): 198-210.

Knetter, Michael. 1993. "International Comparisons of Price-to-Market Behavior." *American Economic Review*, 83(3): 473-86.

Krugman, Paul. 1987. "Pricing to Market When the Exchange Rate Changes," in *Real Financial Linkages Among Open Economies,* eds. S. W. Arndt and J. Richardson, London: MIT Press.

Mussa, Michael. 1986. "Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates." *Carnegie-Rochester Series on Public Policy*, 25: 117-214.

Nakamura, Emi. 2008. "Pass-Through in Retail and Wholesale." *American Economic Review*, 98(2): 430-437.

Nakamura, Emi. 2008. "Accounting for Incomplete Pass-through." mimeo.

Neiman, Brent. 2008. "Intrafirm Trades and International Macro Dynamics." Mimeo. Harvard University.

Ramondo, Natalia, and Andres Rodriguez-Clare. 2008. "The Gains from Openness: Trade, Multinational Production, and Diffusion." Mimeo. University of Texas, Austin.

Appendix 1: Data

Constructing time series of prices

For each product, the retailer keeps record of the retail price and the replacement cost (wholesale price), in each store and week over the period 2004-2006. This replacement cost is net of discounts and inclusive of shipping costs. It is the most comprehensive measure of wholesale prices available to the retailer, and is used by the retailer in its pricing decisions. The data are presented to us in the following way. For each product/store/week, we observe the total revenues and total profits generated to the retailer from sales of that product (i.e., excluding other operational expenses by the retailer). Subtracting profits from total revenues, we obtain the retailer's total cost of acquiring the product from the vendor. Dividing total costs by total quantities, we recover the unit price at which the retailer can acquire the product i,e., the wholesale price. Our measure of retail prices is constructed as the ratio of total revenues to quantities.

Each store is assigned to one of the 73 pricing regions in the US, and one of the 17 pricing regions in Canada. For each product/region pair, we calculate the weekly price as the median weekly price across all stores in that pricing region for which we have data in that specific week, and we calculate quantity sold as the sum of quantities across all stores in the pricing region. Weekly data are aggregated to quarterly data by averaging the data over the weeks within the quarter. In our calculations, we only include products with at least four consecutive observations of price changes.

Calculating product-level statistics

We first calculate the percentage change over time in the relative price between all pairs of pricing regions, for matched products belonging to a set $n \in N$. The set N corresponds to the product category, and/or to the country of production of the good. We then group all the growth rates of all matched products into one of the three following sets according to the country of the pricing region: (i) both pricing regions in the US (vector 1), (ii) both pricing regions in Canada (vector 2), and (iii) one pricing region in Canada and the other in the US (vector 3). $\text{Var}_i^{\text{intra}}$ is equal to the variance of vector 1 for $i =$US and vector 2 for $i =$Canada. $\text{Var}^{\text{inter}}$ is the variance of vector 3. To calculate the correlation of price changes, we proceed as above but construct each of the three vectors using the percentage change in nominal US dollar price, rather than the percentage change in relative price.

Calculating aggregate real-exchange-rates

We first construct $\psi_{nrr't}$, the average expenditure share of product n in region r in country 1 and region r' in country 2, in period t, as follows:

$$\psi_{nrr't} = \frac{P_{n1rt}y_{n1rt} + P_{n2r't}y_{n2r't}}{\sum_n \left(P_{n1rt}y_{n1rt} + P_{n2r't}y_{n2r't}\right)} ,$$

where y_{nirt} is the quantity of product n sold in country i, region r, in period t. To construct the change in the aggregate RER over a set of products N, we first identify, for each pair of quarters t and $t+1$, the set of products $\tilde{N}_t \in N$ for which we observe the product-level RER growth rate between these two quarters. The change in the aggregate RER, ΔQ_t, is given by

$$\Delta Q_t = \sum_{n \in \tilde{N}_t} \sum_{r'=A}^{R_1} \sum_{r=A}^{R_2} \psi_{nrr't-1} \Delta Q_{n21rr't}.$$

We construct ΔQ_t separately for each of the product categories which satisfy the minimum data requirements described in the body of the paper. With these measures, we can aggregate RERs, both at the category-wide level (used in Figure 1), and for the union of all product categories using a weighted average of the different RER's of the various product categories (depicted in Figure 3).

Appendix 2: Additional details of Lemmas 1 and 2

We use the result that $a_{knirt}/\left(z_{knt}W_{tt}\right)$ and $a_{knirt}/\left(z'_{knt}W_{it}\right)$ converge in distribution to time-invariant random variables $1/\bar{z}_{kn}$ and $1/\bar{z}'_{kn}$.

Characterizing the sets of matched products (Lemma 1)

The set of matched products that are supplied by the same producer located in country 1 (and exported to country 2) is given by:

$$N_{x1} = \left\{ n \in N \text{ s.t. } D \min \left\{\bar{z}_{kn}\right\}_{k=1}^{K_1} \leq \min \left\{ \left\{\bar{z}'_{kn}\right\}_{k=1}^{K_1} \cup \left\{\bar{z}_{kn}\right\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \left\{\bar{z}_{kn}, \bar{z}'_{kn}\right\}_{k=K_1+K_2+1}^{K} \right\} \right\}. \tag{7.1}$$

That is, in order for a variety n to belong to this set, the exporter with the minimum marginal cost of supplying country 2, $D \min \{\bar{z}_{kn}\}_{k=1}^{K_1}$, must have a lower marginal cost than (i) all potential multinationals from country 1, $\{\bar{z}'_{kn}\}_{k=1}^{K_1}$, (ii) all local producers from country 2, $\{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2}$, and (iii) all potential exporters from country 3, $D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K}$. Note that if conditions (ii) and (iii) are satisfied for product n, then product n will be also sold domestically. Therefore, any product that is exported from country 1 to country 2 is also active in country 1, and the set N_{x1}, coincides with the set of all exported products from country 1 to country 2. Hence, m_{12} is equal to the mass of the set N_{x1}.

We have

$$m_{12} = \text{Prob}\left(D^{1/\theta} \min \{\bar{u}_{kn}\}_{k=1}^{K_1} \leq \min\left\{\{\bar{u}'_{kn}\}_{k=1}^{K_1} \cup \{\bar{u}_{kn}, \bar{u}'_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^{*1/\theta} \min \{\bar{u}_{kn}, \bar{u}'_{kn}\}_{k=K_1+K_2+1}^{K}\right\}\right)$$

where we used the assumption that $\bar{z} = (\min\{\bar{u}, \bar{u}'\})^{\theta}$. We can solve for this expression as:

$$m_{12} = \begin{cases} \frac{K_1 D^{-1/\theta}}{K_1\left(D^{-1/\theta}+\lambda\right)+K_2(1+\lambda)+K_3 D^{*-1/\theta}(1+\lambda)} & \text{if } D > 1 \\ \frac{K_1(1+\lambda) D^{-1/\theta}}{K_1\left(D^{-1/\theta}+\lambda\right)+K_2(1+\lambda)+K_3 D^{*-1/\theta}(1+\lambda)} & \text{if } D = 1 \end{cases}, \tag{7.2}$$

where we used the assumption that $\bar{u}_{kn}$ and $\bar{u}'_{kn}$ are exponentially distributed.[35][36]

Similarly, the set of matched products that are supplied by the same producer located in country 2 is given by:

$$N_{x2} = \left\{n \in N \text{ s.t. } D \min \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \leq \min\left\{\{\bar{z}_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}'_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min\{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K}\right\}\right\}, \tag{7.3}$$

and the mass of this set is given by:

$$m_{21} = \begin{cases} \frac{K_2 D^{-1/\theta}}{K_1(1+\lambda)+K_2\left(D^{-1/\theta}+\lambda\right)+K_3(1+\lambda)D^{*-1/\theta}} & \text{if } D > 1 \\ \frac{K_2(1+\lambda) D^{-1/\theta}}{K_1(1+\lambda)+K_2\left(D^{-1/\theta}+\lambda\right)+K_3(1+\lambda)D^{*-1/\theta}} & \text{if } D = 1. \end{cases} \tag{7.4}$$

The set of matched products that are supplied by country 3 producers in both countries 1 and 2, N_{x3}, is defined as:

$$N_{x3} = \left\{n \in N \text{ s.t. } D^* \min\{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \leq \min\left\{\{\bar{z}_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2}\right\}\right\}. \tag{7.5}$$

[35] We use the three following properties of exponential distributions. Suppose $u \sim \exp(\mu)$ and $u' \sim \exp(\lambda)$ are independent, and $d > 0$, then (i) $du \sim \exp(\mu/d)$, (ii) $\min\{x, y\} \sim \exp(\mu + \lambda)$, and (iii) $\text{Prob}(x \leq y) = \mu/(\mu+\lambda)$.

[36] In the specific case where there are no iceberg costs, $D = 1$, there is no multinational production and the fraction $\lambda/(1+\lambda)$ of producers with identical cost of exporting and producing abroad choose to export.

That is, in order for a product to be exported from country 3 to both countries, it has to be such that the producer from country 3 with the minimum domestic marginal cost, $D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K}$ has a lower marginal cost than all potential local producers in country 1 and country 2, $\min \left\{ \{\bar{z}_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \right\}$ .The mass of this set is given by:

$$\text{Mass of set } N_{x3} \;=\; \frac{K_3 (1+\lambda) D^{*-1/\theta}}{K_1 (1+\lambda) + K_2 (1+\lambda) + K_3 (1+\lambda) D^{*-1/\theta}}.$$

Note that products that are exported from country 3 to country 1 are not necessarily exported to country 2 (and viceversa). Even though country 3 producers have the same cost of supplying both countries, country 1 and country 2 producers have different supply costs if $D > 1$. To see this, note that the measures of exporters from country 3 to country 1 and country 2 are, respectively:

$$m_{31} = \frac{K_3 (1+\lambda) D^{*-1/\theta}}{K_1 (1+\lambda) + K_2 (D^{-1/\theta} + \lambda) + K_3 (1+\lambda) D^{*-1/\theta}}\ , \tag{7.6}$$

and

$$m_{32} = \frac{K_3 D^{*-1/\theta}}{K_1 (D^{-1/\theta} + \lambda) + K_2 (1+\lambda) + K_3 (1+\lambda) D^{*-1/\theta}}. \tag{7.7}$$

Finally, the set of matched products, N_{dt}, that are supplied by the same domestic producer in each region is composed of two sets: N_{d1} and N_{d2}. The first set, N_{d1}, is given by:

$$N_{d1} = \left\{ \begin{array}{c} n \in N \text{ s.t} \\ \min \{\bar{z}_{kn}\}_{k=1}^{K_1} \leq \min \left\{ \{D\bar{z}_{kn}, \bar{z}'_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \\ \& \ \min \{\bar{z}'_{kn}\}_{k=1}^{K_1} \leq \min \left\{ D \min \{\bar{z}_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \\ \& \ \arg\min \{\bar{z}_{kn}\}_{k=1}^{K_1} = \arg\min \{\bar{z}'_{kn}\}_{k=1}^{K_1} \end{array} \right\} \tag{7.8}$$

There are two conditions that need to be satisfied in order for a variety to belong to the set N_{d1}. First, a producer from country 1 has to sell domestically. This happens if the producer with the lowest local marginal cost, $\min \{\bar{z}_{kn}\}_{k=1}^{K_1}$, has a lower marginal cost than (i) all producers from country 2 who either export from country 2 or produce in country 1, $\{D\bar{z}_{kn}, \bar{z}'_{kn}\}_{k=K_1+1}^{K_1+K_2}$, and (ii) the lowest marginal cost of exporters from country 3, $D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K}$. Second, a producer from country 1 has to sell in the foreign market via MP. This occurs if it has a lower marginal cost than (i) all exporters from country 1 (including itself, since it chose to not to export but instead to engage in MP), $\min \{\bar{z}_{kn}\}_{k=1}^{K_1}$, (ii) all domestic producers from country 2, $\{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2}$, and (iii) all exporters from country

3, $D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K}$. Finally, for consistency, the same producer from country 1 sells in both countries, $\arg\min \{\bar{z}_{kn}\}_{k=1}^{K_1} = \arg\min \{\bar{z}'_{kn}\}_{k=1}^{K_1}$).

N_{d2} is defined in a similar way for country 2 producers:

$$N_{d2} = \left\{ \begin{array}{c} n \in N \text{ s.t.} \\ \min \{\bar{z}_{kn}\}_{k=1+K_1}^{K_1+K_2} \leq \min \left\{ \{D\bar{z}_{kn}, \bar{z}'_{kn}\}_{k=1}^{K_1} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \\ \& \ \min \{\bar{z}'_{kn}\}_{k=1+K_1}^{K_1+K_2} \leq \min \left\{ D \min \{\bar{z}_{kn}\}_{k=1+K_1}^{K_1+K_2} \cup \{\bar{z}_{kn}\}_{k=1}^{K_1} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \\ \& \ \arg\min \{\bar{z}_{kn}\}_{k=1+K_1}^{K_1+K_2} = \arg\min \{\bar{z}'_{kn}\}_{k=1+K_1}^{K_1+K_2} \end{array} \right\} \tag{7.9}$$

We do not provide a simple analytical expression for the mass of sets N_{d1} and N_{d2}.

Characterizing measures of latent competitors (Lemma 1)

We now derive the measures of exporters from country 1 facing the same latent competitor in both countries. These expressions are symmetric for country 2 exporters.

The mass of country 1 exporters facing a latent competitor from country 1 when selling in country 2, s_{12}^1, is:

$$s_{12}^1 = s_1^1 = Pr\left(D \min_2 \{\bar{z}_{kn}\}_{k=1}^{K_1} \ \leq \min \left\{ \{\bar{z}'_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \right).$$

This is the mass of the set of varieties for which the lowest and second-lowest cost exporting producers from country 1 have a lower cost than all other producers supplying country 2.

Similarly, the mass of country 1 exporters facing a latent competitor from country 2 when selling in country 1, s_{12}^1, is:

$$s_{11}^2 = s_1^2 = Pr\left(\begin{array}{c} D \min \{\bar{z}_{kn}\}_{k=1}^{K_1} \ \leq \min \left\{ \{\bar{z}'_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \\ \& \ \min \{D\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \leq \min \left\{ \min_2 \{\bar{z}_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}'_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \end{array} \right)$$

The mass of country 1 exporters facing a latent competitor from country 3 when selling in country 1 is:

$$s_{11}^3 = \Pr\left(\begin{array}{c} D \min \{\bar{z}_{kn}\}_{k=1}^{K_1} \ \leq \min \left\{ \{\bar{z}'_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \\ \& \ \min \{D^*\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \leq \min_2 \{\bar{z}_{kn}\}_{k=1}^{K_1} \end{array} \right).$$

Similarly, the mass of country 1 exporters facing a latent competitor from country 3 when selling in country 1 is:

$$s_{12}^3 = \Pr\left(\begin{array}{c} D \min \{\bar{z}_{kn}\}_{k=1}^{K_1} \ \leq \min \left\{ \{\bar{z}'_{kn}\}_{k=1}^{K_1} \cup \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \cup D^* \min \{\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \right\} \\ \& \ \min \{D^*\bar{z}_{kn}\}_{k=K_1+K_2+1}^{K} \leq \min_2 \{\bar{z}_{kn}\}_{k=K_1+1}^{K_1+K_2} \end{array} \right).$$

The mass of country 1 exporters facing the same latent competitor from country 3 when selling in countries 1 and 2 is:

$$s_1^3 = \Pr\left(\begin{array}{c} D\min\left\{\bar{z}_{kn}\right\}_{k=1}^{K_1} \quad \le \min\left\{\left\{\bar{z}'_{kn}\right\}_{k=1}^{K_1} \cup \left\{\bar{z}_{kn}\right\}_{k=K_1+1}^{K_1+K_2} \cup D^*\min\left\{\bar{z}_{kn}\right\}_{k=K_1+K_2+1}^{K}\right\} \\ \&\ \min\left\{D^*\bar{z}_{kn}\right\}_{k=K_1+K_2+1}^{K} \le \min\left\{\min_2\left\{\bar{z}_{kn}\right\}_{k=1}^{K_1} \cup \left\{\bar{z}_{kn}\right\}_{k=K_1+1}^{K_1+K_2}\right\}\end{array}\right)$$

Note that $s_1^3 \le s_{11}^3$ and $s_1^3 \le s_{12}^3$.

We now derive a closed form solution for these expressions. We introduce the following notation:

$$\begin{aligned}
d &= D^{1/\theta} \\
k_3 &= (1+\lambda)\, K_3/\left(D^*\right)^{1/\theta} \\
\bar{u} &\sim \exp(1) \\
\bar{u}_1 &= \min\left\{\bar{u}_k\right\}_{k=1}^{K_1}\ ;\quad \bar{u}_2 = \min\left\{\bar{u}_k\right\}_{k=K_1+1}^{K_1+K_2}\ ;\ \bar{u}_3 = \min\left\{\bar{u}_k, \bar{u}'_k\right\}_{k=K_1+K_2+1}^{K} \\
\bar{u}' &\sim \exp(\lambda) \\
\bar{u}'_1 &= \min\left\{\bar{u}'_k\right\}_{k=1}^{K_1}\ ;\ \bar{u}'_2 = \min\left\{\bar{u}'_k\right\}_{k=K_1+1}^{K_1+K_2} \\
\bar{u}_1^{2nd} &= \min_2\left\{\bar{u}_k\right\}_{k=1}^{K_1}\ ;\ \bar{u}_2^{2nd} = \min_2\left\{\bar{u}_k\right\}_{k=K_1+1}^{K_1+K_2}
\end{aligned}$$

Define a random variable $\tilde{w} \sim \exp\left(K_2 + k_3 + \lambda\left(K_1 + K_2\right)\right)$. Then,

$$\begin{aligned}
s_{12}^1 &= \Pr\left(d\bar{u}_1 \text{ and } d\bar{u}_1^{2nd} \ < \min\left\{\bar{u}'_1, \bar{u}_2, \bar{u}'_2, \bar{u}_3\right\}\right) = \Pr\left\{\bar{u}_1 < \tilde{w}/d\ ,\ \bar{u}_1^{2nd} < \tilde{w}/d\ \right\} \\
&= \left(K_2 + k_3 + \lambda\left(K_1 + K_2\right)\right)\ \text{x} \\
&\quad \int_0^\infty \Pr\left\{\bar{u}_1 < \tilde{w}/d\ ,\ \bar{u}_1^{2nd} < \tilde{w}/d\ \right\}\exp\left(-\tilde{w}\left(K_2 + k_3 + \lambda\left(K_1 + K_2\right)\right)\right)d\tilde{w} \\
&= 1 - \frac{\left(K_2 + k_3 + \lambda\left(K_1 + K_2\right)\right)}{K_1/d + K_2 + k_3 + \lambda\left(K_1 + K_2\right)} \\
&\quad - \frac{K_1\left(K_2 + k_3 + \lambda\left(K_1 + K_2\right)\right)}{\left(K_1 - 1\right)/d + K_2 + k_3 + \lambda\left(K_1 + K_2\right)} + \frac{K_1\left(K_2 + k_3 + \lambda\left(K_1 + K_2\right)\right)}{K_1/d + K_2 + k_3 + \lambda\left(K_1 + K_2\right)}.
\end{aligned}$$

Define $\tilde{w} \sim \exp\left(k_3 + \lambda\left(K_1 + K_2\right)\right)$. Then,

$$\begin{aligned}
s_{11}^2 &= \Pr\left\{\bar{u}_1 < \bar{u}_2/d\ ,\ \bar{u}_2 < \tilde{w}/d,\ \bar{u}_1^{2nd} > d\bar{u}_2\ \right\} \\
&= K_1K_2\left(k_3 + \lambda\left(K_1 + K_2\right)\right)\ * \\
&\quad \int_0^\infty \int_0^{\tilde{w}/d} \left(1 - \exp\left(-\bar{u}_2/d\right)\right)\exp\left(-\bar{u}_2 d\left(K_1 - 1\right) - \bar{u}_2 K_2\right)dy\,\exp\left(-\tilde{w}\left(k_3 + \lambda\left(K_1 + K_2\right)\right)\right)d\tilde{w} \\
&= K_1K_2\left(k_3 + \lambda\left(K_1 + K_2\right)\right)\ * \\
&\quad \left[\begin{array}{c} \frac{1}{\left(\left(K_1-1\right)d+K_2\right)\left(k_3+\lambda\left(K_1+K_2\right)\right)} - \frac{1}{\left(\left(K_1-1\right)d+K_2\right)\left(\left(K_1-1\right)+K_2/d+k_3+\lambda\left(K_1+K_2\right)\right)} \\ -\frac{1}{\left(1/d+\left(K_1-1\right)d+K_2\right)\left(k_3+\lambda\left(K_1+K_2\right)\right)} + \frac{1}{\left(1/d+\left(K_1-1\right)d+K_2\right)\left(1/d^2+K_1-1+K_2/d+k_3+\lambda\left(K_1+K_2\right)\right)} \end{array}\right]
\end{aligned}$$

Define the random variable $\tilde{w} \sim \exp(K_2 + \lambda(K_1 + K_2))$. Then,

$$\begin{aligned}
s_1^3 &= \Pr\left\{\bar{u}_3 < \tilde{w}, \, \bar{u}_1 < \bar{u}_3/d, \, \bar{u}_1^{2nd} > \bar{u}_3 \right\} \\
&= K_1(K_2 + \lambda(K_1 + K_2)) k_3 \; * \\
&\quad \int_0^\infty \int_0^{\tilde{w}} (1 - \exp(-\bar{u}_3/d)) \exp(-\bar{u}_3(K_1 - 1)) \exp(-\bar{u}_3 k_3) \exp(-\tilde{w}(K_2 + \lambda(K_1 + K_2))) \, d\bar{u}_3 d\tilde{w} \\
&= K_1(K_2 + \lambda(K_1 + K_2)) k_3 \, * \\
&\quad \left[\begin{array}{c} \frac{1}{(K_2+\lambda(K_1+K_2))(K_1-1+k_3)} - \frac{1}{(K_1-1+k_3)(K_2+\lambda(K_1+K_2)+K_1-1+k_3)} \\ -\frac{1}{(K_2+\lambda(K_1+K_2))(1/d+K_1-1+k_3)} + \frac{1}{(1/d+K_1-1+k_3)(K_2+\lambda(K_1+K_2)+1/d+K_1-1+k_3)} \end{array} \right].
\end{aligned}$$

Define the random variable $\tilde{w} \sim \exp(K_2 + \lambda(K_1 + K_2))$. Then,

$$\begin{aligned}
s_{12}^3 &= \Pr\left\{\bar{u}_3 < \tilde{w}, \, \bar{u}_1 < \bar{u}_3/d \, , \, \bar{u}_1^{2nd} > \bar{u}_3/d \right\} \\
&= K_1(K_2 + \lambda(K_1 + K_2)) k_3 \; * \int_0^\infty \\
&\quad \int_0^{\tilde{w}} (1 - \exp(-\bar{u}_3/d)) \exp(-\bar{u}_3/d(K_1 - 1)) \exp(-\bar{u}_3 k_3) \, d\bar{u}_3 \exp(-\tilde{w}(K_2 + \lambda(K_1 + K_2))) \, d\tilde{w} \\
&= K_1(K_2 + \lambda(K_1 + K_2)) k_3 \, * \\
&\quad \left[\begin{array}{c} \frac{1}{((K_1-1)/d+k_3)((K_2+\lambda(K_1+K_2)))} - \frac{1}{((K_1-1)/d+k_3)(K_2+\lambda(K_1+K_2)+(K_1-1)/d+k_3)} \\ -\frac{1}{(K_1/d+k_3)(K_2+\lambda(K_1+K_2))} + -\frac{1}{(K_1/d+k_3)(K_2+\lambda(K_1+K_2)+K_1/d+k_3)} \end{array} \right].
\end{aligned}$$

Define the random variable $\tilde{w} \sim \exp(\lambda(K_1 + K_2))$. Then,

$$\begin{aligned}
s_{11}^3 &= \Pr\left\{\bar{u}_1 < \bar{u}_2/d \, , \, \bar{u}_1 < \bar{u}_3/d, \, \bar{u}_1 < \tilde{w}/d, \, \bar{u}_3 < d\bar{u}_2, \, \bar{u}_3 < \tilde{w}, \, \bar{u}_1^{2nd} > \bar{u}_3 \right\} \\
&= \Pr\left\{\bar{u}_3 < \bar{u}_2, \, \bar{u}_3 < \tilde{w}, \, \bar{u}_1 < \bar{u}_3/d, \, \bar{u}_1^{2nd} > \bar{u}_3 \right\} \\
&\quad + \text{Prob}\left\{\bar{u}_2 < \bar{u}_3 < d\bar{u}_2 \, , \, \bar{u}_3 < \tilde{w}, \, \bar{u}_1 < \bar{u}_2/d \, , \, \bar{u}_1^{2nd} > \bar{u}_3 \right\} \\
&= s_1^3 + \Pr\left\{\bar{u}_2 < \bar{u}_3 < d\bar{u}_2 \, , \, \bar{u}_3 < \tilde{w}, \, \bar{u}_1 < \bar{u}_2/d \, , \, \bar{u}_1^{2nd} > \bar{u}_3 \right\}
\end{aligned}$$

Therefore,

$$\begin{aligned}
s_{11}^3 - s_1^3 &= \Pr\left\{\bar{u}_2 < \bar{u}_3 < d\bar{u}_2 \, , \, \bar{u}_3 < \tilde{w}, \, \bar{u}_1 < \bar{u}_2/d \, , \, \bar{u}_1^{2nd} > \bar{u}_3 \right\} \\
&= K_2 k_3 \; * \\
&\quad \int_0^\infty \int_{\bar{u}2}^{d\bar{u}_2} K_1 (1 - \exp(-\bar{u}_2/d)) \exp(-\bar{u}_3(K_1 - 1)) \;\; \text{x} \\
&\quad \exp(-\bar{u}_3 \lambda(K_1 + K_2)) \exp(-\bar{u}_3 k_3) \exp(-\bar{u}_2 K_2) \, d\bar{u}_3 d\bar{u}_2 \\
&= \frac{K_1 K_2 k_3}{\bar{K}} \left[\frac{1}{K_2 + \bar{K}} - \frac{1}{K_2 + d\bar{K}} - \frac{1}{1/d + K_2 + \bar{K}} + \frac{1}{1/d + K_2 + d\bar{K}} \right].
\end{aligned}$$

where $\bar{K} = K_1 - 1 + \lambda(K_1 + K_2) + k_3$.

We can show that s_{12}^1/m_{12} , s_{11}^2/m_{12}, and s_1^3/m_{12} are all decreasing in d. Therefore, r_1 is also decreasing in d. The proof is available upon request. The same logic applies to r_2.

Appendix 3: Two extensions of the model

Our baseline model assumes that product-level demand shocks are uncorrelated across countries, and that producers have equal marginal costs of supplying both regions within countries. Suppose instead that (i) the cross-country correlation of product-level demand shocks is $\rho_a^{inter} > 0$, and that (ii) producers can locate in different regions within a country. Production in each region is subject to a different idiosyncratic productivity shock, and producers can ship goods across regions subject to an intra-national trade cost (we assume that all regions are symmetric). We focus on the case of small time varying shocks and Bertrand pricing (as in Proposition 2).

Under assumption (ii), producers can face a different local latent competitor in each region. Note that producers will never face two different foreign latent competitors in two regions within a country because we assume that exporters face the same marginal cost of serving the two foreign regions. We define r_i^{intra} to be the fraction of producers in the set N_{xi} facing the same latent competitor in both regions within the same country (in our baseline model, $r_i^{intra} = 1$), and $\bar{r}_i^{intra}$ to be the fraction of producers facing two different latent competitors with the same country-of-production in the two regions within a country. A higher intra-national trade cost lowers r_i^{intra} and raises $\bar{r}_i^{intra}$. We also define r_i^{inter} to be the fraction of producers facing the same latent competitor in two regions in different countries, and $\bar{r}_i^{inter}$ to be the fraction of producers facing two different latent competitors with the same country-of-production in the two regions across countries.

The correlation of price changes across regions within a country is:

$$\text{Correl}_i^{\Delta Pj} = \frac{2\sigma_a^2\rho_a^j + \sigma_z^2 + \sigma_w^2}{2\sigma_a^2 + \sigma_z^2 + \sigma_w^2} r_i^j + \frac{\sigma_w^2}{2\sigma_a^2 + \sigma_z^2 + \sigma_w^2} \bar{r}_i^j \text{ , for } j = \text{intra o inter.}$$

Observe that, given that producers do not always face the same latent competitor in both regions within a country ($r_i^{intra} < 1$), the intra-national correlation of price movements is lower than in our baseline model.

The ratio of inter-to-intra-national variances of product-level RERs is:

$$\frac{\text{Var}_i^{\text{inter}}}{\text{Var}^{\text{intra}}} = \frac{1 - \rho_a^{inter} r_i^{inter} + \frac{\left(\sigma_z^2 + \sigma_w^2\right)}{2\sigma_a^2}\left(1 - r_i^{inter}\right) - \bar{r}_i^{inter}\frac{\sigma_w^2}{2\sigma_a^2}}{1 - \rho_a^{intra} r_i^{intra} + \frac{\left(\sigma_z^2 + \sigma_w^2\right)}{2\sigma_a^2}\left(1 - r_i^{intra}\right) - \bar{r}_i^{intra}\frac{\sigma_w^2}{2\sigma_a^2}}$$

A high inter/intra-national ratio of RER variances can result from a higher likelihood that producers face the same latent competitor across regions within the same country than across regions in different countries ($r_i^{intra} > r_i^{inter}$), and from a higher correlation of demand shocks within than across countries ($\rho_a^{inter} > \rho_a^{inter}$).

The expression that defines the change in aggregate RERs in response to a movement in relative unit labor costs is given by (5.8) where r_i is substituted by $r_i^{inter} - \bar{r}_i^{inter}$.

Figure 1: Canada-US Aggregate-Real Exchange Rates, British Columbia and Northern California

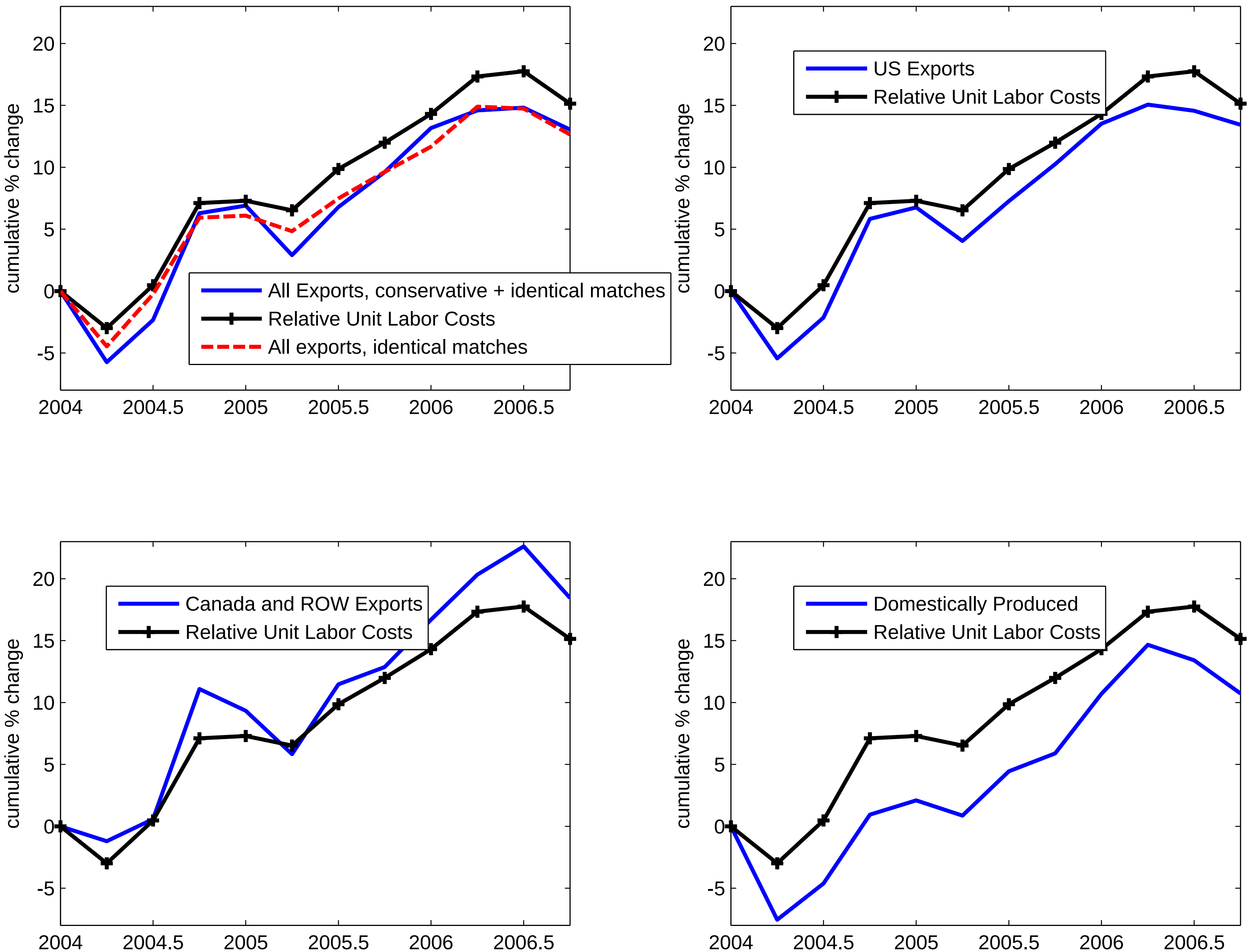


Figure 2: Price Movements for a US Exported Product in the "Tea" Category

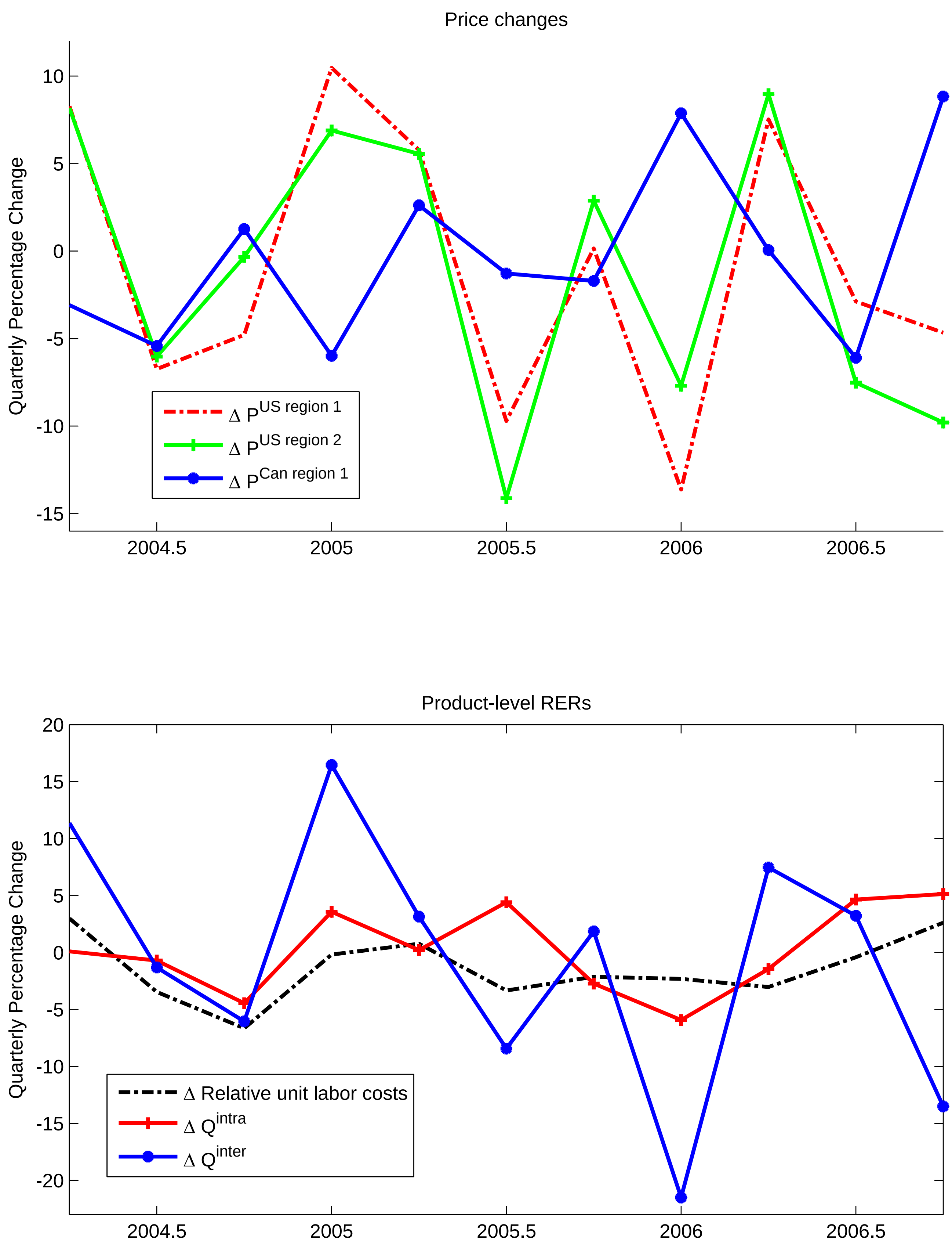
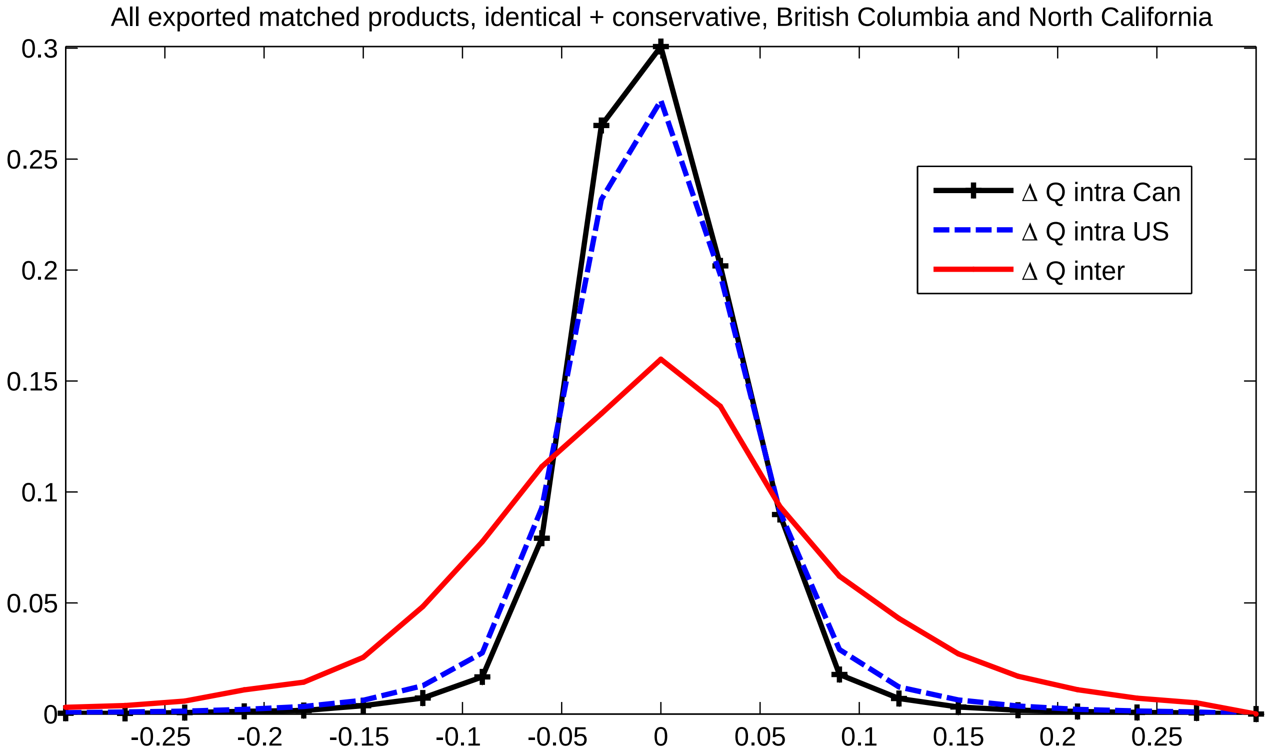


Figure 3: Histogram of Movements of Product-Level Real Exchange Rates



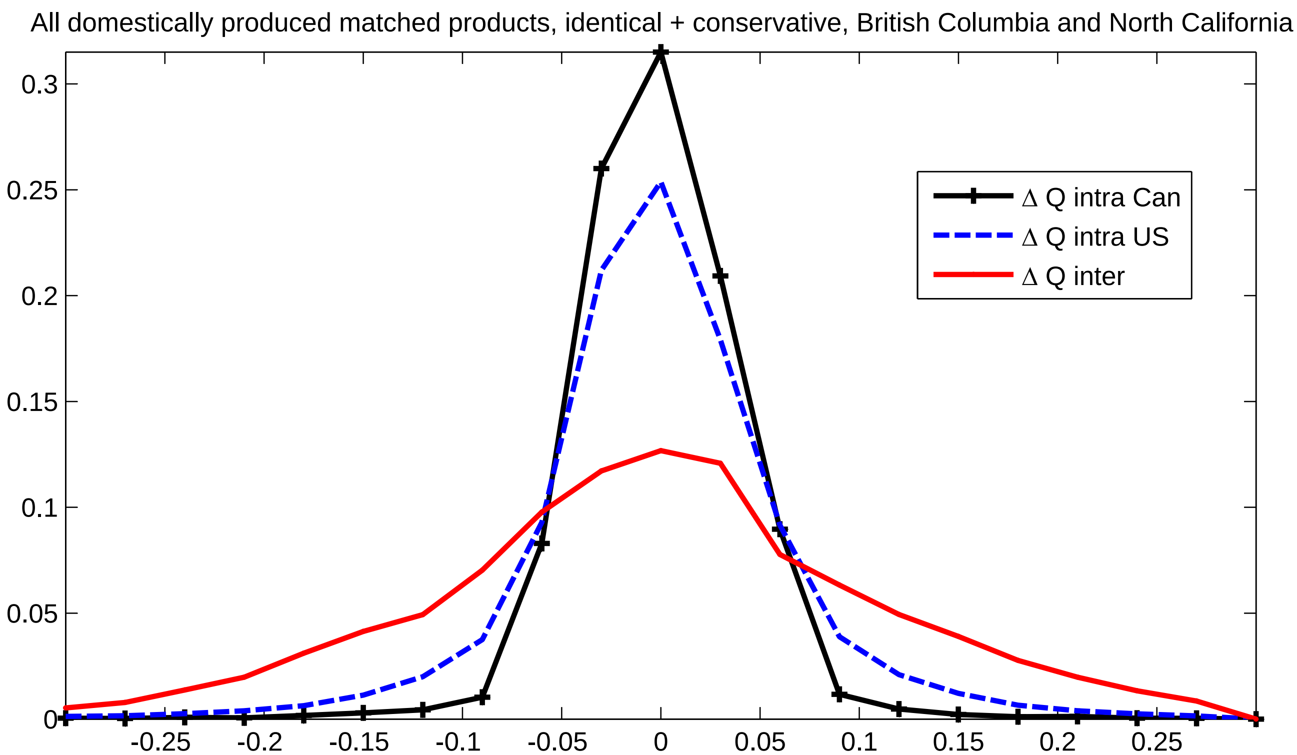
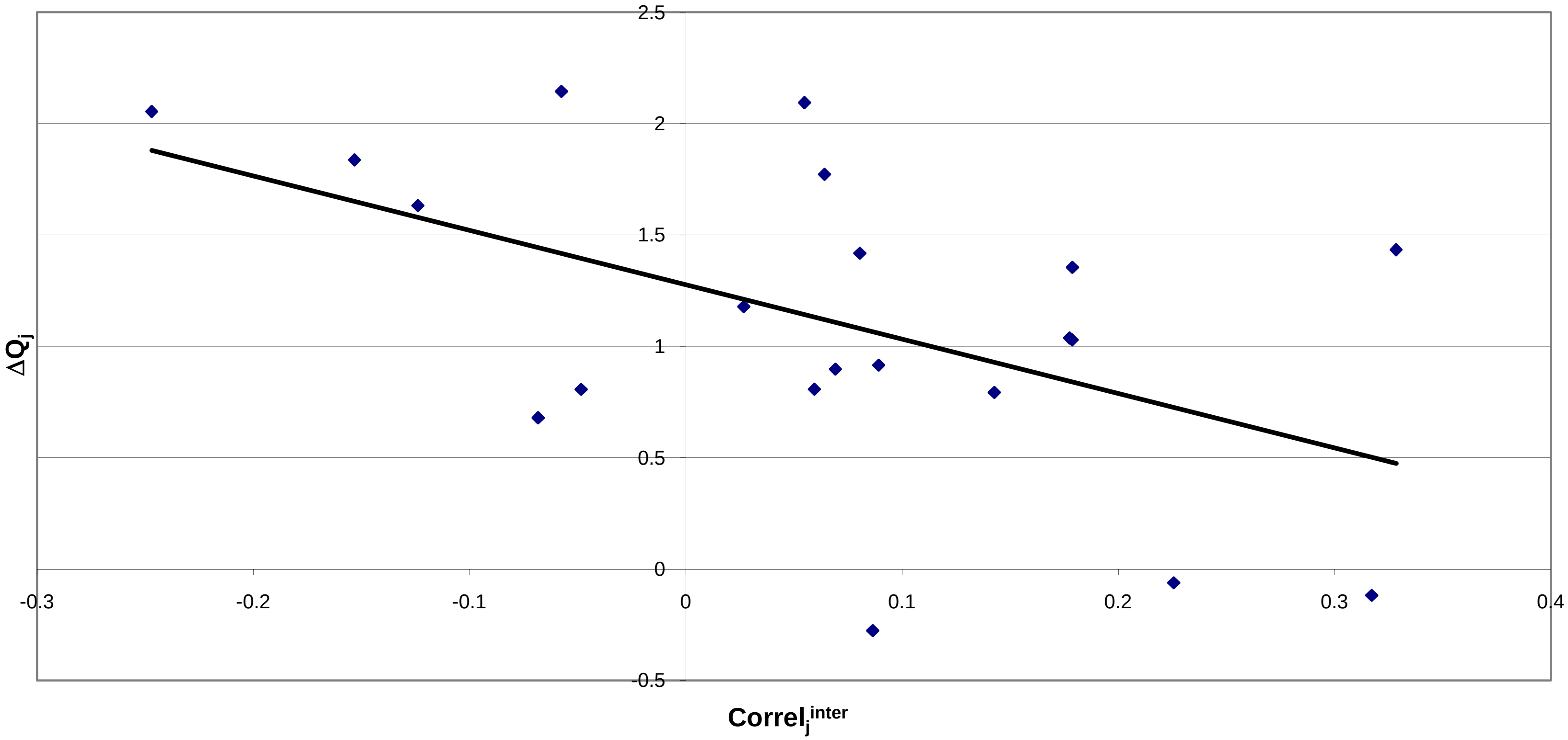


Figure 4: Relation between Product and Aggregate Real Exchange Rates across Product Categories



	Coeff.	*Std. Err.*	*t Stat*
Intercept	1.277	0.148	8.625
X Variable	-2.441	0.938	-2.603

Figure 5: Model Aggregate Real Exchange Rates

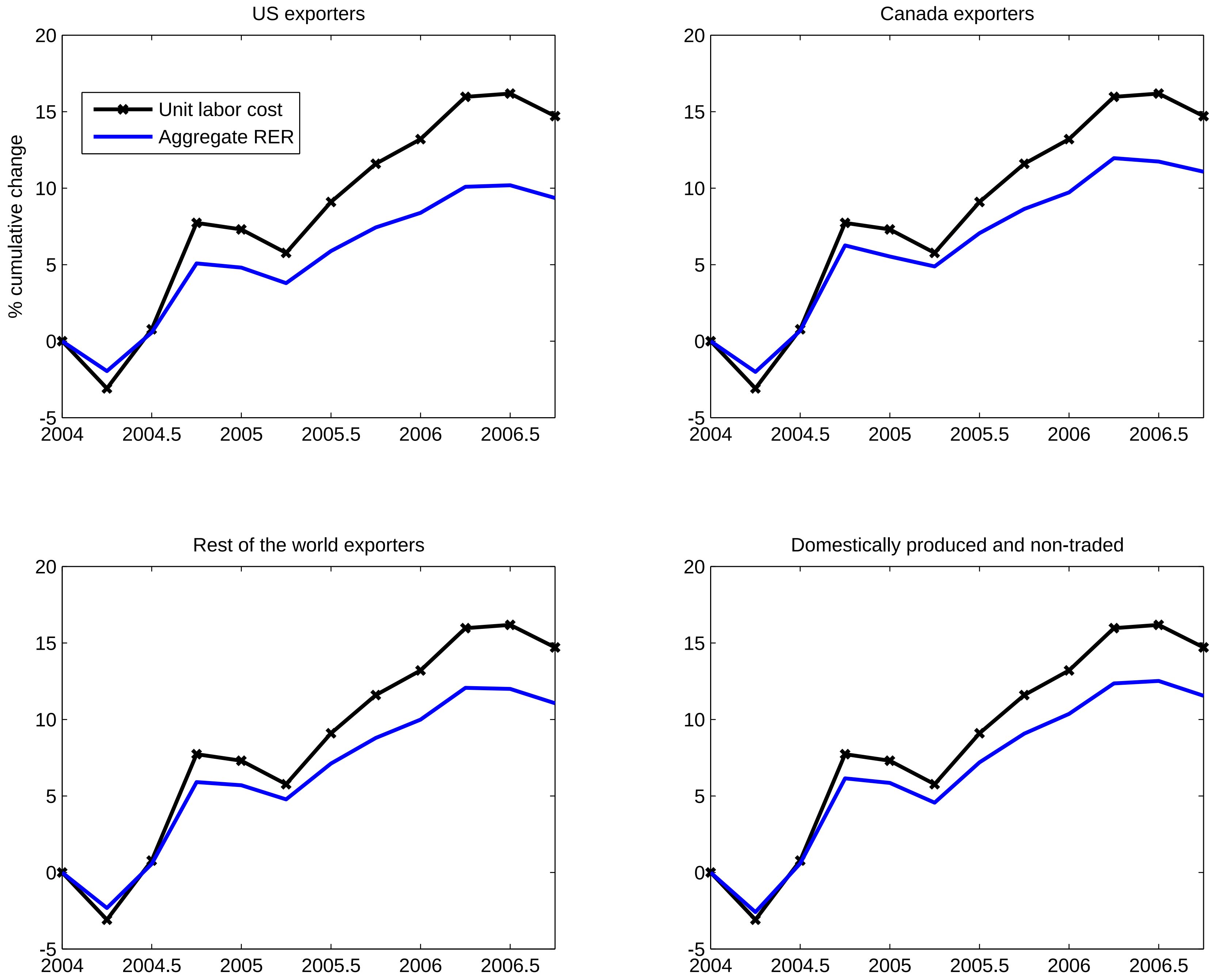


Table 1: Descriptive Statistics

		Panel A: Identical Matches				Panel B: Identical + Conservative Matches			
		Center-West Canada	Center-West US	British Columbia	North California	Center-West Canada	Center-West US	British Columbia	North California
1	**Expenditure share of matched products out of total expenditure**	0.04	0.05	0.04	0.06	0.52	0.36	0.51	0.36
	Expenditure share of unique products produced in:								
2	US	0.60	0.76	0.63	0.73	0.29	0.89	0.30	0.87
3	Canada	0.24	0.03	0.21	0.05	0.68	0.02	0.67	0.01
4	ROW (Same Country)	0.16	0.21	0.16	0.22	0.03	0.09	0.03	0.11
	Number of unique products produced in:								
5	US	573	628	444	543	1522	5278	1477	4185
6	Canada	128	39	105	23	1925	238	1727	161
7	ROW (Same Country)	332	302	179	234	418	636	303	470
	Number of matched products:								
8	Both produced in the US	573	552	444	480	5496	5496	4504	4504
9	Both produced in Canada	44	39	25	23	191	191	124	124
10	Produced and sold in the US and Canada	84	76	80	63	5385	5385	4187	4187
11	Both produced in ROW (same country)	332	302	179	234	367	367	236	236
12	**Number of product categories**	60	55	17	53	93	93	93	93
13	**Number of pricing regions:**	17	51	5	14	17	51	5	14

Center-West includes all pricing regions in Canada (British Columbia, Alberta, and Manitoba), and 51 pricing regions in the US located in California, Oregon, Washington Idaho, Montana, and Wyoming.

Table 2: Movements in Product-Level Real-Exchange Rates

Panel A: Identical + Conservative Matches, North California and British Columbia

		All	All Exporters	US Exporters	Can Exporters	ROW Exporters	Domestic
1	$\mathbf{Std}^{intra,U.S.}$	0.06	0.06	0.06	0.08	0.08	0.07
2	$\mathbf{Std}^{intra,Can}$	0.05	0.05	0.05	0.04	0.07	0.05
3	$\mathbf{Std}^{inter}$	0.13	0.11	0.10	0.14	0.14	0.13
4	$\mathbf{Correl}^{intra,U.S.}$	0.75	0.73	0.73	0.71	0.73	0.79
5	$\mathbf{Correl}^{intra,Can}$	0.84	0.80	0.80	0.89	0.77	0.88
6	$\mathbf{Correl}^{inter}$	0.07	0.09	0.10	0.05	0.09	0.07

Panel B: Identical Matches, North California and British Columbia

		All	All Exporters	US Exporters	Can Exporters	ROW Exporters	Domestic
7	$\mathbf{Std}^{intra,U.S.}$	0.09	0.09	0.09	0.08	0.10	0.07
8	$\mathbf{Std}^{intra,Can}$	0.07	0.08	0.07	0.04	0.09	0.05
9	$\mathbf{Std}^{inter}$	0.13	0.13	0.12	0.09	0.15	0.10
10	$\mathbf{Correl}^{intra,U.S.}$	0.52	0.53	0.56	0.36	0.47	0.45
11	$\mathbf{Correl}^{intra,Can}$	0.72	0.72	0.72	0.78	0.71	0.79
12	$\mathbf{Correl}^{inter}$	0.09	0.10	0.10	0.00	0.09	-0.03

Panel C: Identical Matches, Center-West Canada and Center-West US

		All	All Exporters	US Exporters	Can Exporters	ROW Exporters	Domestic
13	$\mathbf{Std}^{intra,U.S.}$	0.07	0.07	0.07	0.06	0.09	0.06
14	$\mathbf{Std}^{intra,Can}$	0.07	0.07	0.06	0.03	0.09	0.05
15	$\mathbf{Std}^{inter}$	0.13	0.13	0.12	0.08	0.15	0.10
16	$\mathbf{Correl}^{intra,U.S.}$	0.68	0.68	0.68	0.45	0.70	0.56
17	$\mathbf{Correl}^{intra,Can}$	0.76	0.76	0.76	0.85	0.75	0.83
18	$\mathbf{Correl}^{inter}$	0.11	0.12	0.13	0.00	0.10	-0.06

Table 3: Movements in Product-Level Real-Exchange Rates, Sensitivity Analysis

A: Liberal Matches

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$	0.06	0.06	0.05	0.10	0.07	0.07
2	**Std**^{intra,Can}	0.04	0.04	0.03	0.02	0.08	0.04
3	**Std**^{inter}	0.13	0.11	0.11	0.17	0.14	0.15
4	**Correl**$^{intra,U.S.}$	0.77	0.74	0.75	0.68	0.74	0.79
5	**Correl**^{intra,Can}	0.93	0.89	0.90	0.96	0.74	0.94
6	**Correl**^{inter}	0.07	0.05	0.06	-0.04	0.09	0.09

B: Center-West pricing regions

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$	0.06	0.06	0.06	0.09	0.09	0.07
2	**Std**^{intra,Can}	0.04	0.04	0.04	0.05	0.07	0.04
3	**Std**^{inter}	0.12	0.11	0.11	0.15	0.14	0.13
4	**Correl**$^{intra,U.S.}$	0.77	0.73	0.75	0.72	0.65	0.78
5	**Correl**^{intra,Can}	0.87	0.86	0.88	0.88	0.77	0.88
6	**Correl**^{inter}	0.07	0.06	0.05	0.08	0.08	0.07

C: One pricing region in Seattle and in British Columbia

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$						
2	**Std**^{intra,Can}						
3	**Std**^{inter}	0.12	0.11	0.11	0.15	0.15	0.12
4	**Correl**$^{intra,U.S.}$						
5	**Correl**^{intra,Can}						
6	**Correl**^{inter}	0.07	0.06	0.05	0.08	0.10	0.08

D: Four pricing regions: BC, Manitoba, NC, Illinois

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$	0.08	0.08	0.08	0.10	0.09	0.08
2	**Std**^{intra,Can}	0.04	0.05	0.04	0.04	0.07	0.04
3	**Std**^{inter}	0.12	0.11	0.11	0.20	0.15	0.13
4	**Correl**$^{intra,U.S.}$	0.61	0.59	0.57	0.84	0.62	0.62
5	**Correl**^{intra,Can}	0.87	0.82	0.82	0.92	0.78	0.91
6	**Correl**^{inter}	0.06	0.07	0.08	-0.03	0.06	0.05

E: Prices Demeaned by Category-wide price

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$	0.06	0.06	0.05	0.09	0.07	0.06
2	**Std**^{intra,Can}	0.04	0.04	0.04	0.03	0.05	0.04
3	**Std**^{inter}	0.12	0.11	0.11	0.21	0.13	0.13
4	**Correl**$^{intra,U.S.}$	0.78	0.76	0.76	0.71	0.74	0.79
5	**Correl**^{intra,Can}	0.88	0.86	0.86	0.95	0.84	0.90
6	**Correl**^{inter}	0.07	0.09	0.09	0.00	0.13	0.06

F: Prices Demeaned by Nominal Wage

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$	0.06	0.06	0.05	0.09	0.07	0.06
2	**Std**^{intra,Can}	0.04	0.04	0.04	0.03	0.05	0.03
3	**Std**^{inter}	0.12	0.11	0.10	0.15	0.13	0.13
4	**Correl**$^{intra,U.S.}$	0.78	0.76	0.76	0.73	0.74	0.79
5	**Correl**^{intra,Can}	0.88	0.85	0.85	0.95	0.84	0.89
6	**Correl**^{inter}	0.08	0.10	0.10	0.07	0.11	0.07

G: Retail Prices, Identical Matches, NC and BC

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$	0.08	0.08	0.08	0.05	0.09	0.05
2	**Std**^{intra,Can}	0.05	0.05	0.05	0.03	0.05	0.04
3	**Std**^{inter}	0.12	0.12	0.12	0.07	0.13	0.09
4	**Correl**$^{intra,U.S.}$	0.73	0.73	0.73	0.59	0.71	0.77
5	**Correl**^{intra,Can}	0.80	0.80	0.81	0.70	0.76	0.82
6	**Correl**^{inter}	0.06	0.07	0.07	0.15	0.06	-0.04

H: Retail Prices, Identical + Conserv. Matches, NC and BC

		All	All exp.	US exp.	Can. exp.	ROW exp.	Domestic
1	**Std**$^{intra,U.S.}$	0.08	0.07	0.07	0.08	0.07	0.10
2	**Std**^{intra,Can}	0.05	0.05	0.05	0.04	0.05	0.04
3	**Std**^{inter}	0.14	0.14	0.14	0.17	0.13	0.14
4	**Correl**$^{intra,U.S.}$	0.75	0.75	0.75	0.89	0.77	0.75
5	**Correl**^{intra,Can}	0.85	0.83	0.83	0.81	0.05	0.87
6	**Correl**^{inter}	0.08	0.03	0.03	0.18	0.01	0.13

NC: Northern California, BC: British Columbia

Table 4 : Baseline Parameterization: Parameter Values and Targets

Panel A: Parameter values

	Parameters that determine trade patterns		
1	K_1	28	
2	K_2	4	
3	K_3	5	
4	D	1.58	
5	D*	1.15	
6	λ	0.35	
7	θ	0.3	
	Parameters that determine price movements	**Uncorrelated demand shocks**	**Correlated demand shocks**
8	σ_z	0.054	0.034
9	$\sigma_z^2/(\sigma_z^2+\sigma_a^2)$	0.780	0.333
10	ρ_a	0	0.64

Panel B: Targets

	Trade shares		**Source**
11	Exports Can to US , share of US expenditures, selected industries	2%	Source OECD
12	Exports US to Can , share of Can expenditures, selected industries	25%	Source OECD
13	Average Exports ROW to Can, ROW to US, share of US,Can expenditures, selected industries	10%	Source OECD
14	Expenditures in Nd / Expenditures in Nx1 and Nx2 , Canada	1%	Our data
	Prices		
15	Standard deviation price changes, US exporters, average US and Canada, Region 2	8%	Our data
16	Intra-national correlation of price changes, US exporters average US and Canada , Region 2	0.82	Our data
17	International correlation of price changes, US exporters average US reference and Canada reference , Region 2	0.08	Our data
18	Canada-US relative unit labor costs, overall apreciation 2004-2006	15%	OECD

Table 5: Quantitative Results, Baseline Parameterization

		Uncorrelated demand shocks	Correlated demand shocks
	Panel A: Product-level price statistics		
	US Exporters		
1	Correlation intranational prices	0.75	0.74
2	Correlation international prices	0.26	0.11
3	St. dev. inter / intra RER	1.72	1.87
	Canadian Exporters		
4	Correlation intranational prices	0.73	0.73
5	Correlation international prices	0.19	0.08
6	St. dev. inter / intra RER	1.85	1.96
	ROW Exporters		
7	Correlation intranational prices	0.74	0.74
8	Correlation international prices	0.17	0.08
9	St. dev. inter / intra RER	1.87	1.95
	Domestically Produced		
10	Correlation intranational prices	0.74	0.74
11	Correlation international prices	0.18	0.07
12	St. dev. inter / intra RER	1.85	1.94
	Panel B: Aggregate price statistics		
	Change in RER / Change in relative wages		
13	*US Exporters*	0.64	0.63
14	*Canadian Exporters*	0.75	0.73
15	*ROW Exporters*	0.76	0.74
16	*Domestically Produced*	0.78	0.79

Table 6: Quantitative Results, Sensitivity Analysis

		1	2	3	4	5	6	7
		Baseline $\rho_a = 0$	Small shocks	Correl intra prices = 0.55	Lower MP $\lambda = 0.15$	$\theta = 0.45$	$\theta = 0.2$	$\eta = 0.2$
Panel A: Product-level price statistics								
	US Exporters							
1	Correlation intranational prices	0.75	0.75	0.55	0.75	0.74	0.75	0.75
2	Correlation international prices	0.26	0.20	0.19	0.25	0.24	0.31	0.32
3	Variance inter / intra RER	1.72	1.90	1.33	1.74	1.73	1.67	1.68
	Canadian Exporters							
4	Correlation intranational prices	0.73	0.75	0.52	0.74	0.73	0.74	0.70
5	Correlation international prices	0.19	0.14	0.14	0.18	0.16	0.22	0.20
6	Variance inter / intra RER	1.85	1.99	1.42	1.90	1.85	1.84	1.65
	ROW Exporters							
7	Correlation intranational prices	0.74	0.76	0.54	0.74	0.74	0.75	0.72
8	Correlation international prices	0.17	0.12	0.13	0.14	0.15	0.21	0.22
9	Variance inter / intra RER	1.87	2.02	1.43	1.92	1.86	1.86	1.71
	Domestically produced							
10	Correlation intranational prices	0.74	0.76	0.54	0.74	0.74	0.75	0.71
11	Correlation international prices	0.18	0.14	0.13	0.14	0.15	0.22	0.11
12	Variance inter / intra RER	1.85	2.00	1.41	1.90	1.85	1.81	1.81
Panel B: Aggregate price statistics								
	Change in RER / Change in relative costs							
13	*US Exporters*	0.64	0.71	0.64	0.64	0.66	0.60	0.53
14	*Canadian Exporters*	0.75	0.81	0.75	0.76	0.77	0.71	0.69
15	*ROW Exporters*	0.76	0.83	0.76	0.79	0.78	0.72	0.67
16	*Domestically produced*	0.78	0.81	0.78	0.83	0.80	0.75	0.87

In all cases we adjust the remaining parameters to match the other calibration targets.