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PRICE SETTING IN ONLINE MARKETS:
BASIC FACTS, INTERNATIONAL COMPARISONS, AND CROSS-BORDER INTEGRATION

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ABSTRACT

We document basic facts about prices in online markets in the U.S. and Canada, a rapidly growing segment of the retail sector. Relative to prices in regular stores, prices in online markets are more flexible as well as exhibit stronger pass-through (60-75 percent) and faster convergence (half-life less than 2 months) in response to movements of the nominal exchange rate. Multiple margins of adjustment (frequency of price changes, direction of price changes, size of price changes, exit of sellers) are active in the process of responding to nominal exchange rate shocks. Furthermore, we use the richness of our dataset to show that degree of competition, stickiness of prices, synchronization of price changes, reputation of sellers, and returns to search effort are important determinants of pass-through and speed of price adjustment for international price differentials.

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1. Introduction

E-commerce is a rapidly increasing segment of the retail market. For example, the U.S. Census Bureau estimated that total e-commerce sales for 2013 were $263.3 billion, or approximately 5.6 percent of total retail sales in the U.S. economy. This represents an increase of 16.9 percent from 2012 while total retail sales increased by 4.2 percent in 2013, which is consistent with historical trends: online sales have grown much faster (10 or more percent) than sales of brick-and-mortar stores. Forrester Research, an independent technology and market research company, predicts that by 2016 online sales will account for more than 9 percent of total retail sales.[1] However, despite a significant and rapidly expanding share of e-commerce, the properties of online prices are still relatively understudied even though these prices can shed new light on a number of key puzzles.

Indeed, online markets have unique qualities. For example, the physical cost of changing prices is negligible for internet stores and therefore internet prices could be fluctuating every instant (minute, day, week) in response to shifting demand and supply conditions. Search for best online prices for very narrowly defined goods is particularly cheap and simple as consumers do not need to travel anywhere, buyers can establish the distribution of prices with just a few clicks, and pressure for price convergence is especially strong with ubiquitous price comparison websites. More generally, the geographical location of consumers and stores is largely irrelevant in e-commerce and therefore administrative borders and similar frictions are likely to play a much more limited role.

These special qualities of online markets can help understand why pass-through of exchange rate fluctuations and reversion to the law of one price are generally weak in international data and thus constitute one of the central puzzles in international economics (Obstfeld and Rogoff 2000). In a highly integrated market with low frictions of price adjustment, easy search and price comparisons, and limited influence of geographical barriers, one can rule out some popular explanations of the puzzle and narrow down the set of plausible theories. Using internet prices in the U.S. and Canada for a broad array of products, we try to exploit these insights and provide new evidence on the nature and sources of frictions in price adjustment and departures from the law of one price.

To document and study the properties of online prices, we have constructed a unique dataset of price quotes. Specifically, for almost 5 years we scraped prices and other relevant information from a leading price comparison website. The data include each good's unique identifier (similar

[1] These patterns are very similar in other developed countries. For example, according to the Centre for Retail Research, online retail sales in Europe jumped 20 percent this year, far outstripping the 1.4 percent growth in store-based sales. Furthermore, the share of online sales in total sales is larger in Europe than in the USA. For instance, the share is 9.5 percent in the U.K.

to barcodes in the scanner price data), each good's description, prices for each seller, each seller's unique identifier, the number of seller reviews, the ranking of seller quality, reviews of goods, etc. The dataset covers a broad range of goods sold online including software, movies, music, electronics, tools, and others. We have collected information for more than 140,000 goods and more than 11 million price quotes.

There are several advantages of using our data. First, the time span (almost 5 years) is considerably longer than the time span usually available for researchers studying online prices (typically a year or less). This dimension is important when we study dynamic properties of prices such as duration of price spells, speed of price convergence, and pass-through. Second, the coverage of goods is much broader than in previous analyses of online prices which typically focused on books and CDs. The latter types of goods are easy to compare across sellers or countries but they also have a number of unusual properties which make generalizations difficult. Our dataset is heavily populated by durable goods which tend to be under-represented in typical scanner price data and which are much more likely to be traded and moved across distant locations. Third, we collected prices for identical goods in the U.S. and Canada so that comparison of prices is direct and simple. Thus, we can avoid a number of pitfalls associated with comparing goods that are only broadly similar or comparing price indexes. Fourth, our data include information on important attributes such as the reputation of sellers and goods as revealed by ratings of sellers and products. We can use these attributes to explore the determinants of properties of online prices. In contrast, previous research on basic properties of prices had only very limited (if any) information about properties of goods for which prices were available. Fifth, our data include many sellers rather than one retail chain and therefore we can assess the relative importance of different sources of price variation (e.g., store-level, country-level, etc.). This multi-seller dimension is important because branches of a single seller are less likely to engage in competition between each other than with branches of different sellers. Finally, the high frequency of our data allows us to time reactions of prices to other high frequency events such as changes in the exchange rate or natural experiments thus making identification more clear-cut.

Using this dataset, we report properties of various pricing moments (e.g., the frequency and size of price changes) in e-commerce and thus complement influential studies by Bils and Klenow (2004) and Nakamura and Steinsson (2008) presenting the same information for regular brick-and-mortar stores. We find that the size of price changes in online stores (approximately 4 percent) is less than half the size of price changes in regular stores (approximately 10 percent). We also find that price changes occur much more frequently in online stores (approximately once every 3 weeks or less) than in regular stores (once every 4-5 months or more). This evidence is consistent with the view that online prices are much more flexible than prices in regular stores. However, the fact that we still observe some rigidity in online prices suggests that the costs of changing prices are more complex than just physical menu costs and instead are likely to involve costs of gathering and processing information as well as potentially coordinating price changes with customers, suppliers or other sellers. We also document that price dispersion is substantial and persistent, even for very narrowly defined goods. For example, the average standard deviation of log prices in a given week for a precisely defined good at the bar-code level is approximately 0.12.

Once these basic facts are established, we study the sensitivity of online prices to fluctuations of the nominal exchange rate. Since adjustment of online prices is unlikely to have any physical costs and, with easy shipping, the physical location of the seller is much less important, the pass-through could be quick and nearly complete while it can be slow and partial in the prices of regular stores because of the frictions associated with trade flows and mobility of buyers. We find that, on average, the pass-through in online markets is incomplete but large and amounts to approximately 60-75 percent, which is greater than the 20-40 percent pass-through documented for regular markets. The speed of price adjustment to equilibrium levels is substantially faster in online markets (half-life is about 2-2.5 months) than in regular markets (half-life varies from 3 quarters to a few years).

There is significant heterogeneity in pass-through and the speed of price adjustment across goods. Using the richness of our data, we show that for goods with certain characteristics the pass-through can be close to 100 percent. We also document that the size of the pass-through and the speed of price adjustment are systematically associated with the degree of price stickiness, turnover of sellers, returns to search, synchronization of price changes, reputation of sellers, and the degree of competition. These results help reconcile the heterogeneity of estimated pass-throughs and speeds of adjustment across studies and provide new facts for theoretical models to match.

In summary, the stylized facts we document about prices in online stores relative to prices in regular, brick-and-mortar stores are: 1) the duration of price spells is shorter; 2) the size of price change is smaller; 3) pass-through is larger; 4) the speed of price adjustment is faster; 5) dramatic heterogeneity of the pass-through and the speed of adjustment is systematically related to fundamental properties of the goods and the markets in which these goods are sold. Most of these findings are consistent with reduced frictions and increased integration in online markets and thus can inform policymakers and researchers about what one may expect to observe when frictions in regular markets are reduced.

This paper is related to several strands of research. The first strand is focused on assessing whether the law of one price (or its milder versions such as the purchasing power parity (PPP) hypothesis) holds and how quickly deviations from the law of one price are eliminated. The early generation of this literature could use only price indexes collected at the country or regional level, which led to a number of practical and conceptual issues with the interpretation of the results. Rogoff

(1996) summarizes this literature as documenting that PPP is likely to hold in the long run but it takes a long time for prices to converge to the PPP (half-life is routinely estimated to be over a year and in most cases multiple years). This literature also found that deviations from PPP can be quite large and heterogeneous across countries and time (e.g., Takhtamanova 2010, Campa and Goldberg 2005, Barhoumi 2005) which can be only partially explained by sticky prices and exchange rate regimes, constituting the PPP puzzle.[2]

Data limitations of the first strand motivated the second generation of studies which focused on using micro-level price data to measure pass-through and the speed of price adjustment for goods defined more precisely. Imbs et al. (2005, 2010), Crucini and Shintani (2008), Broda and Weinstein (2008), and others showed that the pass-through and the speed of price adjustment are higher when prices for narrowly-defined goods are considered: the half-life of price adjustment falls to about a year. These papers demonstrate that the PPP puzzle observed in price indexes can be explained at least to some extent by aggregation biases. Because the micro-level price data are richer and easier to compare across countries, the second generation studies can also provide a more detailed account of the relative importance of producer-currency pricing (PCP) versus pricing-to-market (PTM) hypotheses. For example, Gopinath et al. (2011) find support for the PTM hypothesis in explaining incomplete pass-through in the weekly scanner (barcode level) price data for a retailer selling goods in both the U.S. and Canada. We contribute to this literature by examining the behavior of prices at the level of precisely defined goods sold by multiple stores in different countries.

Easier access to micro-level price data also allowed exploring the determinants of pass-through and speed of price adjustment. For example, Menon (1996), Kardasz and Stollery (2001), Gaulier et al. (2006), Goldberg and Hellerstein (2013), Mayoral and Gardea (2011) relate market structure, market power (including adjustment of mark-ups), tariffs, presence of multinationals, and importance of non-traded inputs for price stickiness of final goods and the size of pass-through. We contribute to this literature by exploring the determinants of pass-through and speed of price adjustment for online markets.

The third strand of research we contribute to is focused on documenting price rigidities at the micro-level which could be used later to calibrate macroeconomic models, see e.g. Bils and Klenow (2004) and Nakamura and Steinsson (2008). Studies in this literature concentrate almost exclusively on prices collected in regular, brick-and-mortar stores. In contrast, we focus on online prices which describe a rapidly growing part of the retail sector. Online prices will play an increasingly important role in the future and, thus, macroeconomists should incorporate properties

[2] This literature also related trade frictions to the level of price dispersion. See Engel (1993), Engel and Rogers (1996) and Gorodnichenko and Tesar (2009).

of a broader set of goods, including goods sold online, when they characterize micro-foundations of their macroeconomic models.

The fourth strand documents basic facts about properties of online prices. In a study representative of this literature, Brynjolfsson and Smith (2000) compare online and conventional-store prices for books and CDs. They find that online prices are 9-16 percent lower than prices in regular stores, the changes in online prices are much smaller for online prices, yet quotes of internet prices are quite dispersed even for precisely defined goods. Much of the subsequent literature tried to, mostly theoretically, explain dramatic dispersion of prices in online markets (e.g., Baye and Morgan 2001, Baye and Morgan 2004, Morgan, Orzen, and Sefton 2006, Baye and Morgan 2009) by information frictions (e.g., bounded rationality), sellers' ability to discriminate consumers (e.g., based on what sellers know about customers),[3] and differences in advertisement (e.g., investment in building brand reputation). We provide evidence that considerable price dispersion in online markets applies to a very broad set of goods.

The previous studies most relevant for our paper are Lünnemann and Wintr (2011), Boivin et al. (2012), and Cavallo et al. (2014). Lünnemann and Wintr (2011) document stickiness of online prices in the U.S. and large European markets (Germany, France, Italy, and the U.K.). They find that internet prices change less often in the U.S. than in Europe (the opposite is true for conventional stores). Online prices are more flexible than their offline counterparts with half of the spells ending within a month. However, the result is not universal as it does not hold for subsets of goods, nor it is homogeneous across shops, which can exhibit significant differences. In contrast, Boivin et al. (2012) focus on the dynamics of online price differences across three book sellers: Amazon.com (and Amazon.ca), BN.com (Barnes & Noble website), and Chapters.ca. They find that price differentials (or relative quantities) for books do *not* react to fluctuations in the relative price of foreign competitors following exchange rate movement which is consistent with extensive market segmentation and pervasive violations of the law of one price. Similar to Boivin et al. (2012), Cavallo et al. (2014) collect online prices for four large retailers (Apple, H&M, Zara, and IKEA) in a number of countries and document that the violations of the law of one price (e.g., they compare prices for a given IKEA product in IKEA websites in Germany and Sweden) appear only for countries outside currency unions and arise at the time goods are introduced rather than at later stages of product life when shocks can move real exchange rates for goods. We merge these lines by exploring a larger set of goods, using longer time series and price quotes from multiple sellers, exploiting significant movements in the nominal exchange rate, and investigating determinants of observed pass-through and speed of price adjustment.

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[3] For example, Deck and Wilson (2006) study discrimination based on search history which can indicate how a customer informed is about prices for a given good.

The rest of the paper is structured as follows. In the next section we describe the dataset and how it was collected. In Section 3, we document the basic properties of online prices. In Section 4, we do extensive international price comparisons. We estimate the pass-through and the speed of price adjustment for online prices. In addition, we explore the determinants of the size and speed of price adjustment in response to changes in the nominal exchange rate. In Section 5, we discuss our results and make concluding remarks.

2. Data Description

A. Data collection

This study uses data collected from a price comparison website which provides price quotes for two countries: USA (.com domain) and Canada (.ca domain).[4] Styles of pages with price quotes are similar across countries which simplifies data extraction and identification of exactly identical products listed by Canadian and U.S. sellers. Identifiers for goods listed on the website are similar to barcodes used in the analysis of scanner price data. For example, manufacturing product number (MPN) 0S03110 uniquely identifies Hitachi Touro Mobile Pro Portable External 750 GB 2.5" Hard Drive. Figure 1 shows screenshots of typical web-pages from price comparison websites.

Although the price comparison platform we use has similar websites in other countries, we limit the set of countries to the U.S. and Canada. This choice is motivated by several reasons. First, the link between the U.S. and Canadian websites greatly simplifies linking goods across countries. Second, trade flows are more likely to be affected by trans-ocean shipping costs, language differences, etc. if we compare prices in, for instance, Japan and the U.S. Finally, we want to study countries with strong trade ties. The U.S.-Canada pair is ideal in this respect as flows of goods and services between these two countries are strong even for online markets. For example, Statistics Canada (2013) reports that 63 percent of Canadian online shoppers placed an order with a U.S. online store in 2012. This is comparable to the 82 percent share of Canadian online shoppers who placed an order with a Canadian online store.

In contrast to a few previous studies that investigate properties of online prices and typically have up to one year of data (e.g. Lünnemann and Wintr 2011), our data cover almost five years. The data collection was launched on November 16, 2008 and continued until September 2013. Importantly, this timeframe includes a period of significant appreciation of the Canadian dollar against the U.S. dollar from 1.30 in the end of 2008 to 0.95 in the middle of 2011 (see Figure 2).

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[4] The U.S. part of the website was among the top 10 Web portals based on total unique visitors in January 2010. Comscore, January 2010. The website reported in 2012 that tens of millions of people visited it every month.

Longer time series combined with significant changes in the exchange rate will help us to obtain precise estimates.

Every Saturday at midnight, a Tcl/python script has been triggered to collect webpages with price information. The script has several stages. First, it collects information on the universe of goods available for a given type of goods on the comparison website. For each good, there exists a link to a unique webpage with price quotes. The script constructs a dictionary of goods and associated links. Second, the script follows the links and downloads webpages with price quotes. It usually takes about 24 to 48 hours to download a complete set of pages for all goods in targeted categories. Third, after the webpages are downloaded, the python part of the script extracts good description, unique manufacturing product number (MPN), prices for each seller, and sellers' unique ids from every webpage. Our price quotes are net prices (i.e., prices *before* taxes and shipping/handling costs). Figure 3 shows an example of price quotes extracted from the webpages for a good popular in the U.S. and Canada. Whenever possible, we also collected gross prices (i.e., net prices plus taxes and shipping/handling costs) where the destination was an address in Berkeley, CA. Gross prices are available for about a half of net price quotes.

In the end, we have obtained information for more than 140,000 goods and 11 million good-seller-week-country quotes. Our price data covers 55 types of goods in four main categories: computers (20 types, e.g., laptops), electronics (13 types, e.g., GPS), software (12 type, e.g., computer games), and cameras (10 types, e.g., digital cameras). Table 1 presents the list of categories and types of goods in our sample.[5] We focus on these categories of goods because online purchases are particularly relevant for these goods (Gorodnichenko et al. 2014) This selection of goods, the length of the time sample, and variation in exchange rates in our time sample provides us with a number of advantages relative to what researchers used in previous studies.[6]

First, our dataset covers a relatively diverse set of goods while the vast majority of papers on online prices almost exclusively focused on books or CDs for which it was relatively easy to ensure that the same good is compared across sellers. Prices of these goods have, however, a number of unusual properties such as very long spells of constant prices. Furthermore, the market for books and CDs is dominated by a handful of major sellers such as Amazon.com and Barnes&Noble. Thus, it may be hard to generalize results beyond books and CDs. The diversity of goods in our sample will be essential when we study determinants of the size of exchange rate pass-through and the speed of price adjustment.

[5] The price comparison website has been introducing more detailed categories over time. To ensure consistency in our data, we use the classification of goods available at the time when we started to collect our data.

[6] We have no information on the quantities of goods bought at quoted prices and some price quotes may be irrelevant for consumers. However, in another dataset with online quotes and clicks associated with these quotes, Gorodnichenko et al. (2014) found that pricing moments are similar for equally weighted price quotes and for price quotes weighted by clicks.

Second, a great deal of research studying the law of one price has been using data on goods for which transaction costs for cross-border purchases are likely to outweigh even large departures from the law of one price. For example, consumers are unlikely to directly take advantage of arbitrage opportunities in grocery products which are typically available in scanner price data or cost-of-living surveys (e.g., Economist Intelligence Unit). In contrast, we focus on goods for which transaction costs are small and consumers are essentially free to exploit even small arbitrage opportunities. Indeed, goods in our sample are durable, standardized, and easy to ship. Most goods in our sample are produced outside the U.S. or Canada and marginal cost shocks can be effectively differenced out when we take the ratio of Canadian and U.S. prices. These qualities are also likely to limit the importance on non-tradables which often account for a significant share of the cost of selling goods in regular stores.

Third, goods in our data are precisely defined and therefore one can be more certain that he or she compares prices of the same good when he or she contemplates a purchase. For example, we treat as separate goods red and blue iPods which otherwise share exactly the same technical characteristics. This contrasts with previous research using price indexes or prices for broadly defined goods (e.g., toothpaste).

Fourth, our dataset collects price quotes from multiple sellers while previous research (e.g., Gopinath et al. 2011, Cavallo et al. 2014) typically used micro-level price data from one seller (e.g., because scanner price data are supplied by one retail chain). This aspect is important because branches of the same seller in different countries (e.g., Amazon.com and Amazon.ca) are less likely to compete with each other than outlets of different sellers (e.g., Amazon.com and BHphotovideo.com). Our data covers a broad spectrum of sellers such as large general stores (Amazon, Newegg), large specialized or branded stores (B&H or Dell), and niche stores (Memory4less).

Finally, data are collected at weekly frequency which allows us to study responses of prices at relatively high frequency and makes identification cleaner.

B. Data filters

Because price data are extraordinarily heterogeneous in our sample, we apply a series of filters to minimize the effects of missing values, extreme observations and the like. Specifically, we winsorize prices of goods at top and bottom 1 percent. For time series analyses focused on dynamic responses or control for lagged values of variables, we keep only goods with at least twenty consecutive observations. We consider three commonly used procedures to deal with missing values (see Coibion et al. (2012) for a discussion). The first procedure ("A") assumes that a price spell ends when there is a price change or a missing value. The second procedure ("B") combines spells on both sides of a missing spell provided the price before and after the missing spell is unchanged.

Suppose we observe a price of $1 during weeks 2 to 3 and the price for weeks 4 to 6 are missing, but we observe a price of $1 for week 7 followed by $1.5 for week 8 and $1.4 for week 9. The length of the ($1) spell is 2+1=3 weeks. The third procedure ("C") imputes the previously observed price to all missing values. In the example above, this means that we include weeks 4 to 6, resulting in a ($1) spell length of 2+3+1 = 6. We will make calculations based on procedure C as the benchmark but we find similar results with procedures A and B. We use imputations only to calculate the duration of price spells. Finally, because we are interested in international price comparisons, we constrain the sample only to goods that were sold by both U.S. and Canadian online sellers.

These filters reduce the number of goods in our sample from 140,000 to about 12,000. We verified that selection into the estimation sample is likely to be random as various pricing moments are approximately the same in the full and the estimation samples. For example, Appendix Figure 1 shows that the distribution of price levels for the estimation sample is close to the distribution for the full sample. Appendix Table 1 demonstrates that the key moments are very similar for the full and estimation samples.

C. Data quality

Price comparison websites are convenient aggregators of price information. Consumer Futures (2013), a statutory representative of consumers in the U.K., reports that 56 percent of *all* shoppers use price comparison websites in some way: to hunt for bargains (85 percent of who use price comparison websites), compare prices (83 percent), identify providers (69 percent), buy goods (52 percent), etc. 95 percent of internet users are aware of price comparison websites. E-commerce merchants use price comparison websites to attract new customers and increase sales.[7] Price comparison websites have a great multiplier as they send data to thousands of sites worldwide.

Price comparison websites routinely allow automatic export of product feed so that whenever an online seller changes a good's price, the new price is immediately reflected on price comparison websites. Online sellers are also interested in keeping their price as current as possible because they often pay for clicks on price comparison websites and, if a price is outdated or a good is out of stock, online sellers waste money. However, there could be systematic discrepancies between prices reported on price comparison websites and prices listed on the websites of sellers

[7] Online sellers do not put every product they sell on price comparison websites because these websites may charge a fee per listing. (However, some price comparison engines scrape prices from webpages of online sellers who do not submit their listings.) As a result, online sellers may list only goods with competitive prices. While such behavior can affect some moments of the data (e.g., frequency of price changes), it is not a problem for our analysis of international price comparisons. Indeed, the very nature of online markets is such that competition is fierce, turnover is high, and search for best prices is cheap. Hence, only the best prices are relevant for consumers and end up being transaction prices.

because, for example, online sellers may engage in "bait and switch" strategies. To assess the quantitative importance of this concern, we compare prices from both sources (that is, from the price comparison website and from a seller listed on the price comparison website) for a random sample of 100 goods.[8] Specifically, a script clicks on a link for each seller listed on our price comparison website and collects price information from the seller's webpage (if necessary, this information is checked manually).

We find (Figure 4) that, while there are some discrepancies, price quotes (Panel A) are remarkably consistent across sources. When we aggregate price quotes across sellers and focus on the average price for a given good (Panel B), the difference between the sources is small. The differences are somewhat larger when we consider dispersion of prices across sellers measured in terms of standard deviation (Panel D) and interquartile range (Panel C). However even for price dispersion, the price comparison website provides quite accurate information. If we regress a moment based on prices from sellers' websites on the corresponding moment based on prices from the price comparison website, we get an estimated slope close to one and estimated intercept close to zero with R^2 approaching to one. We cannot reject equality of moments across the sources of price information. We conclude that the quality of price data from the price comparison website is high.

3. Basic facts about price setting in online markets

Table 2 shows descriptive statistics for our data. Let *i*, *t*, *s*, *c* index goods, time (weeks), sellers, and countries. The average log price $\log P_{itsc}$ in our sample is 5 (or approximately $150). This magnitude is significantly larger than the level of prices considered in previous studies (e.g., with scanner price data or online prices of books and CDs) where goods routinely have prices below $10. It is also not unusual in our sample to observe prices of goods above $600 (approximately 75th percentile) or $1400 dollars (approximately 90th percentile). Since we will focus on how quickly cross-border arbitrage opportunities dissipate, the level of prices is important since search effort is likely to be larger for big-price-tag items. Also note that the level of prices is approximately the same in the U.S. and Canada.

Goods routinely have multiple sellers in our data. The average number of sellers is approximately 2.3 in Canada and 3.6 in the U.S. This is consistent with the notion that the U.S. market is larger than the Canadian market but the difference is not as striking as one observes in the numbers of regular brick-and-mortar stores in two countries. In part this difference is smaller because online markets tend to be more concentrated. We also observe that the stability of sellers—

[8] We are extremely grateful to Alberto Cavallo for generating price data from websites of online sellers and sharing these data with us.

we define stability as the ratio of the number of stores selling a good in a given week to the number of stores ever selling this good in the month which covers the given week—is a bit larger in Canada (0.423) than in the U.S. (0.405).

Similar to previous studies of online prices (e.g., Brynjolfsson and Smith 2000, Baye et al. 2006), we observe dramatic cross-sectional dispersion of prices which is calculated as

$$\sigma_{itc} \equiv \left\{\frac{1}{\#(\mathcal{S}_{itc})}\sum_{s\in\mathcal{S}_{itc}}\left(\log P_{itsc} - \frac{1}{\#(\mathcal{S}_{itc})}\sum_{s\in\mathcal{S}_{itc}}\log P_{itsc}\right)^2\right\}^{0.5},$$

where $\mathcal{S}_{itc}$ is the set of stores that sell good i in week t in country c. On average across goods and time periods, the standard deviation of log prices within a country is 0.128-0.151, which is significant but smaller than one can observe for the dispersion of prices across regular stores.[9,10] Given that the levels of prices are large in our sample, these price differentials correspond to significant dollar amounts. In some cases, the differences between cheapest and most expensive prices are in multiple hundreds of dollars which could be surprising given easy search for the best prices in online markets. However, we do observe that the size of price differentials is negatively correlated with the level of prices. That is, more expensive goods tend to have smaller (log) price dispersion. We also find that the cross-sectional dispersion of prices in any given market is fairly persistent. The serial correlation of log or level of standard deviation of log prices in a given week is routinely above 0.85.

The duration of price spells depends on the treatment of missing values in price quotes and the treatment of small price changes. We define a price change as a movement in prices larger than one percent in absolute value. We discard very small price changes (less than one percent in absolute value) as these changes are likely to arise from measurement errors (e.g., Eichenbaum et al. 2014). The mean price spell is the shortest with procedure A (approximately 1.4-1.5 weeks) and the longest with procedure C (approximately 3.0-4.1 weeks). The duration of price spells is a little longer in the U.S. than in Canada. Overall, the duration of price spells is considerably shorter for online prices than for prices observed in the scanner price data (e.g., Kehoe and Midrigan 2010), in government surveys of prices (e.g., Bils and Klenow 2004, Nakamura and Steinsson 2008), or in online prices for books (e.g., Boivin et al. 2012) where mean duration of price spells is at least several months. The duration of price spells we document, however, is consistent with Lünnemann and Wintr (2011) who analyze a similar set of goods but have data only for one year.[11]

[9] For example, Coibion et al. (2012) report that the standard deviation in the log price for a given unique product code (UPC), a given market (metro area) and a given week is 28% on average across periods, markets and UPCs.
[10] Rating of sellers is a strong predictor of price deviations for a given good and, thus, some price dispersion is due to compensating differentials for seller reputation. However, the dispersion remains high even after controlling for store rankings.
[11] We experimented with using ∧- and ∨-shaped filters as in Nakamura and Steinsson (2008) to identify sales. We found that removing sales does not materially affect our results.

Price increases and decreases are equally likely in our data. The average price change is slightly negative which captures the fact that goods in our sample are subject to technical improvements over time and thus prices of existing goods tend to depreciate with the age of goods. The median absolute log price change is approximately 4 percent in both countries, which is again similar to facts documents in Lünnemann and Wintr (2011). In contrast, Nakamura and Steinsson (2008) document for regular prices in brick-and-mortar stores that the average absolute price change is about 10 percent for goods in the consumer basket and for goods similar to goods in our sample. Shorter durations of price spells and smaller sizes of price changes for online prices than for prices in regular stores are consistent with menu costs being smaller for online sellers than for regular stores. However, the non-negligible rigidity of online prices suggests that there are other costs associated with price changes (e.g., collecting and processing information) which make prices somewhat inflexible.

As a final measure of price stickiness, we consider synchronization of price changes across sellers. Specifically, we define synchronization in a given week for a given good as the fraction of price quotes with a price change conditional on a least one price change and having at least two sellers at this point in time:

$$Synchronization_{itc} = \frac{\sum_{s\in\mathcal{S}_{itc}} \mathbf{1}\{P_{itsc} \neq P_{i,t-1,sc}\} - 1}{\sum_{s\in\mathcal{S}_{itc}} \mathbf{1}\{P_{itsc} \neq \text{missing} \cap P_{i,t-1,sc} \neq \text{missing}\} - 1},$$

where we code $Synchronization_{itc}$ as missing if $\sum_{s\in\mathcal{S}_{itc}} \mathbf{1}\{P_{itsc} \neq P_{i,t-1,sc}\} < 1$. The average synchronization is 19 percent in the U.S. and 30 percent in Canada. Given that there are on average three stores for a given good in a given week, the magnitude of this fraction points to little synchronization of price changes across sellers. However, there is considerable heterogeneity in synchronization across goods.[12]

4. International price differentials

A. Descriptive statistics

We focus on two popular measures of international price differentials: the relative exchange rate $\log(P_{it}^{CA}/P_{it}^{US})$ and the real exchange rate $\log\left(EX_t^{-1} \times P_{it}^{CA}/P_{it}^{US}\right)$ where *i* and *t* index goods and time, P_{it}^{CA} (P_{it}^{US}) is a price measure for a given good in Canada (U.S.), EX is the CAD/USD nominal exchange rate. Since for any given period/good/country, there are multiple sellers and hence multiple prices, we consider several measures of prices at the country level: mean price across sellers; median price across sellers; minimum price across sellers; mean price weighted by the

[12] We present selected statistics by category of goods in Appendix.

reputation of sellers (reputation is measured as the number of stars, from 1 to 5, that consumers assign to sellers). For the last measure we use two imputations for sellers with no information about their reputation (i.e., no stars are assigned): assign the lowest possible score (one star) or the middle of the range (2.5 stars). Each of these measures has pros and cons. For example, while the mean price was often used in previous research, median prices are less sensitive to extreme price quotes. In light of Chevalier and Kashyap (2011) and Baye et al. (2009), one may conjecture that minimum prices are closer to transaction prices and thus are more likely to capture prices relevant for consumers. Finally, while price is the most important factor in the comparison process, the reputation of sellers is a factor in choosing where to buy a good and it may be reasonable to give a higher weight to sellers with high ratings (Consumer Futures 2013).[13]

Irrespective of which measure of prices we use, international price differentials are moderately large and mildly persistent (Table 3). The AR(1) coefficient is between 0.80 and 0.92 (at weekly frequency) depending on whether we control for good/type fixed effects. These estimates correspond to half-life of 3 to 6 week, which is much shorter than half-lives (typically about a year) estimated on prices collected in regular stores. The mean of $\log(P_{it}^{CA}/P_{it}^{US})$ and $\log\left(EX_t^{-1} P_{it}^{CA}/P_{it}^{US}\right)$ is about 5 to 13 percent. Some of the price dispersion across countries could be explained by differences in taxes. For example, the value added tax (federal and provincial) in Canada is about 13 percent and there is big variation in sales taxes across U.S. states.[14] However, differences in taxes are unlikely to be the whole story. First, there is dramatic variation in price differentials (columns (4) and (5) in Table 3): the 25th percentile of the mean price differential is close to zero while the 75th percentile is between 15 and 25 percent. If price differentials were mainly determined by taxes, one would expect to see little if any variation in price differentials across goods or over time. Second, for a subsample of goods we have information for gross prices that include taxes and shipping costs, we observe similar international price differentials (Appendix Table 1).[15]

The standard deviation of price differentials across countries—which ranges from 0.23 to 0.28 see column (2) in Table 3—is 50 to 100 percent larger than the standard deviation of price differentials within countries, which is between 0.12 and 0.14. This finding is qualitatively consistent with results reported in the earlier literature comparing price differentials within and across countries (e.g., Engel and Rogers 1996). However, moments for the real and relative

[13] We also constrained our sample to include sellers with 4+ star reviews. We found similar results. See Appendix Table 6.

[14] Although we use an address in Berkeley, CA, online sellers with no physical presence in California do not have to collect sales tax (close to 10 percent) on behalf of the state of California. As a result, Californian consumers often pay no sales tax on their online purchases.

[15] The price comparison webpage was redesigned for various goods in various times and in many versions of the webpages we could specify the location of the buyer and thus obtain net and gross prices. We used the address of the department of economics at UC Berkeley as the shipping destination. Gross prices are available for about half of quotes for which we have net prices.

exchange rates are broadly similar so that fluctuations in the nominal exchange rate are unlikely to be the main factor in cross-border price differentials.

In summary, properties of online price differentials are qualitatively similar to properties of prices in regular markets but the magnitude and persistence of price differentials are smaller relative to counterparts reported in previous studies for brick-and-mortar stores. Thus, this first pass at the data suggests that frictions are much smaller in online markets but non-negligible cross-sectional dispersion of prices and some persistence of price differentials are consistent with some border frictions in online markets. In the following sections, we will examine determinants of these persistent and volatile cross-border price differentials in online markets.

B. Pass-through and the speed of price adjustment

To characterize the dynamics of cross-border price differentials, one commonly uses two metrics: pass-through (i.e., how movements in the nominal exchange rate are translated into movements of prices of goods) and the speed of price adjustment to equilibrium levels. While there is a variety of versions of these two metrics, we employ two basic econometric specifications to construct these metrics:

Pass-through α: $$\log\left(\frac{P_{it}^{CA}}{P_{it}^{US}}\right) = \alpha EX_t + Controls + error_{it}, \quad (1)$$

Speed of price adjustment β: $$d\log\left(\frac{P_{it}^{CA}}{P_{it}^{US}}\right) = \beta\left(\log\left(\frac{P_{i,t-1}^{CA}}{P_{i,t-1}^{US}}\right) - \alpha EX_{t-1}\right) + \phi_1 d\log\left(\frac{P_{i,t-1}^{CA}}{P_{i,t-1}^{US}}\right) + \lambda_1 dEX_{t-1} + Controls + error_{it} \quad (2)$$

where $Controls$ is a set of control variables and $dx_t \equiv x_t - x_{t-1}$ is the first difference operator.[16] Specification (1) estimates the long-run pass-through and is similar to specifications estimated in Goldberg and Knetter (1997), Campa and Goldberg (2005), Goldberg and Hellerstein (2013). The law of one price predicts that α should be equal to one and, hence, values of α closer to one correspond to smaller departures from the law of one price. Specification (2) is set in the error-correction/cointegration form where β quantifies how quickly the deviation from equilibrium is eliminated. More negative values of β mean faster adjustment. In Specification (2), equilibrium relationship between relative and the exchange rate (coefficient α) is determined according to specification (1).[17] Thus, while the equilibrium relationship nests the law of one price, it also allows deviations from the law of one price (i.e., α can be less than one). Since we use an estimated α in

[16] We use BIC to select the number of lags for $d\log\left(P_{i,t-1}^{CA}/P_{i,t-1}^{US}\right)$ and dEX_{t-1}. Results are similar when we allow for more lags.

[17] We found similar results when we restrict $\alpha = 1$.

equation (2), one may be concerned about the consistency of estimated β as well as using standard inference for estimated β. These concerns are unlikely to be quantitatively important for several reasons. First, exchange rates are fairly persistent and approach a unit root so that an estimate of α in specification (1) can be super-consistent. Second, the error terms in specifications (1) and (2) are essentially uncorrelated and thus adjustment for the generated regressors is minimal. Hence, we can first estimate specification (1) and then use $\hat{\alpha}$ to construct the deviation from equilibrium relationship in specification (2). In our preferred specification, $Controls$ include good fixed effects.

Table 4 reports estimated specifications (1) and (2) on pooled data.[18] To account for the fact that error terms in specifications (1) and (2) can be correlated across time, goods, and countries as well as the fact that EX_t is common across goods and countries, we use the Driscoll and Kraay (1998) standard errors. Note that for specification (2) we have fewer observations because we restrict the sample only to price quotes with at least one spell of twenty consecutive observations without imputations.

The estimated exchange rate pass-through is about 60 to 75 percent which is considerably larger than 20 to 40 percent pass-through typically reported in previous studies based on prices collected from regular stores (Menon 1996, Kardasz and Stollery 2001, Goldberg and Verboven 2001, Barhoumi 2005, Campa and Goldberg 2005, Gaulier et al. 2006, Takhtamanova 2010, Gopinath and Rigobon 2008, Cao et al. 2012). This increased pass-through is consistent with salient features of online markets: i) prices are more flexible, ii) competition is fierce, iii) consumers can easily buys goods from the U.S. or Canada, iv) distribution/non-tradable costs are small, and v) most goods are produced overseas so that the costs are similar across countries.

Estimated β's suggest fast correction of prices toward a long-run equilibrium. If we abstract from the short-run dynamics (i.e., ϕ and λ) in specification (2), 7 percent or more of the gap from the long-run relationship is closed in a week (or correspondingly about 25 percent of the gap is closed in a month and 60 percent in a quarter) which implies the half-life of 2-2.5 months or less. This speed of adjustment is considerably faster than the speed estimated on price indexes (e.g., Rogoff (1996) estimates a half-life of 3 to 5 years) or scanner price data where prices of exact same goods sold in regular stores are compared across countries (e.g., Broda and Weinstein (2008) estimate a half-life of 2.9 quarters). This speed of price adjustment, however, would probably not surprise observers of the online markets. For example, Baye et al. (2007) emphasize that i) online customers compare prices within goods, not within stores; ii) the number of sellers and prices changes frequently; and iii) firms need to constantly monitor prices of their rivals. All of these factors are likely to accelerate price adjustment. Yet, the speed of adjustment we find is much higher than the speed estimated by Boivin

[18] Appendix Table 5 presents estimates for data aggregated to monthly frequency.

et al. (2012) for online prices of books. This discrepancy in the results is likely to reflect the specifics of book markets which tend to have much stickier prices and higher market power of sellers.

Panel C presents estimates of the pass-through and the speed of price adjustment when U.S and Canadian prices are compared within sellers (e.g., price quotes for the same good in Amazon.com and Amazon.ca). While the pass-through is larger for intra-seller prices than for all price quotes in the specification without fixed effects, the pass-through is smaller once we condition on good fixed effects. This lower magnitude is consistent with the notion that sellers present in both online markets can price discriminate consumers in Canada and the U.S. and reduce competition between their branches in different countries. This result may explain why previous studies (e.g., Gopinath et al. 2011, Cavallo et al. 2014) using price comparisons across branches of the same seller in different countries tend to find low pass-through.

C. Determinants of pass-through and speed of price adjustment

While in the previous section we focus on pooled estimates of pass-through and the speed of price adjustment to present simple summary statistics, there is dramatic heterogeneity of these characteristics across goods (Table 5) when we estimate α and β at the level of individual goods. A key question is what factors are systematically related to the size of the pass-through and the speed of price adjustment. Usually, it is hard to answer this question because the data are available only at the aggregate level or little is known about the properties of goods and, as a result, previous research (e.g., Yang 1997, Campa and Goldberg 2005) focused on macroeconomic determinants (e.g., exchange rate regime, level of inflation) of pass-through. Fortunately, our dataset contains information about a number of potentially important determinants at the micro level.

First, Head et al. (2010), Richards et al. (2014) and others argue that the degree of pass-through is negatively related to search costs. The return to search effort should be higher for expensive goods. For example, consumers are more likely to search for better deals on computers and plasma TVs than on toothpaste or beer. A higher search intensity should put a larger pressure on price convergence across sellers and countries. Thus, one may expect that more expensive goods should exhibit a larger pass-through and faster speed of price adjustment. Our dataset has a wide distribution of goods in terms of their prices and we can exploit this variation to examine and quantify this channel. Specifically, we can use the log median price over the sample to proxy for returns on search.

Second, a number of studies (Rogoff 1996, Apslund and Friberg 2001, Bergin and Feenstra 2001, Imbs et al. 2005, Mayoral and Gadea 2011, Devereux and Yetman 2010, Takhtamanova 2010) suggested that price stickiness could be an important force in determining how deviations from the law of one price are eliminated. With flexible prices, adjustment could be deep and quick. In contrast, sticky prices could delay price adjustment and make it incomplete. We can measure the degree of price stickiness using the mean frequency of price changes for a given good in our sample. More frequent price changes should be associated with larger pass-through and faster price adjustment.

Third, the degree of synchronization in price changes can be important because pass-through and speed of price adjustment could be affected not only by the degree of price stickiness at the level of individual seller but also to what extent price setting is staggered (see Neiman 2010). Indeed, in many macroeconomic models, one needs staggered price setting in addition to strategic complementarity to generate gradual adjustment of prices. As argued by Bhaskar (2002) and others, if prices are set simultaneously (i.e., synchronization is high), the reaction of prices to shocks is stronger and departures from equilibrium levels are quickly eliminated.

Fourth, Dornbusch (1987), Feenstra et al. (1996), Atkeson and Burstein (2008) and many others emphasize that market power can affect the magnitude of pass-through. While the theory often stresses market share, we do not have information on sales of individual stores and we will use a proxy for the degree of market power. Specifically, the number of sellers should be indicative of the degree of competition. With more sellers, one should expect a larger pass-through and the speed of adjustment.

Fifth, Gust et al. (2010) argue that firm entry can increase exchange rate pass-through. Indeed, an easier entry into selling a good is likely to make competition stronger (e.g., hit-and-run strategy) and, as a result, make pass-through larger and price adjustment faster. A stronger turnover of sellers is likely to be indicative of how easy it is to start selling a given good. We proxy for the turnover using our stability measure (a more stable set of sellers means a lower turnover) and hence we should expect a negative correlation between stability and pass-through and between stability and speed of price adjustment.

Finally, reputation of sellers can influence pass-through and speed. Specifically, consumers are more likely to take advantage of price differentials if sellers of a given good have high reputation because price differentials then likely present a genuine opportunity to have a good deal rather than capture a compensating differential for lack of reputation or heterogeneity in some other dimension (see Imbs et al. 2010 for a discussion). This logic suggests that pass-through and speed should be high if sellers have high reputation.

To test these predictions, we estimate specifications (1) and (2) for each good separately and then regress estimated $\hat{\alpha}$ and $\hat{\beta}$ on the factors we describe above:

$$\begin{aligned}\hat{\alpha}_i = {} & \gamma_1 \log(\bar{P}_i) + \gamma_2[\log(\bar{P}_i)]^2 + \gamma_3 Frequency_i + \gamma_4 \log(Sellers_i) + \gamma_5[\log(Sellers_i)]^2 \\ & + \gamma_6 StabilitySellers_i + \gamma_7 Synchronization_i \\ & + \gamma_8 Reputation_i + T_i + C_i + error_i \qquad (3)\end{aligned}$$

$$\begin{aligned}\hat{\beta}_i = {} & \delta_1 \log(\bar{P}_i) + \delta_2[\log(\bar{P}_i)]^2 + \delta_3 Frequency_i + \delta_4 \log(Sellers_i) + \delta_5[\log(Sellers_i)]^2 \\ & + \delta_6 StabilitySellers_i + \delta_7 Synchronization_i \\ & + \delta_8 Reputation_i + T_i + C_i + error_i \qquad (4)\end{aligned}$$

where i indexes goods, $\bar{P}_i$ is the median price of good i in Canada, $Frequency_i$ is the mean frequency of price changes in Canada, $Sellers_i$ is the number of sellers of good i in the U.S. and Canada, $StabilitySellers_i$ is the stability of sellers in the U.S. and Canada for good i, $Synchronization_i$ is the degree of synchronization of price changes for good i in the U.S. and Canada, $Reputation_i$ is the average star rating of U.S. and Canadian sellers for good i, number of T_i is a set of fixed effects for periods over which $\hat{\alpha}_i$ and $\hat{\beta}_i$ are estimated, C_i is a set of fixed effects for categories of goods. Each variable on the right-hand side is calculated as the time series average. For example, $Synchronization_i = \frac{1}{2T}\sum_{t=1}^{T}\sum_{c=\{CA,US\}} Synchronization_{itc}$.[19] Table 6 reports estimated coefficients for specification (3) in Panel A and specification (4) in Panel B by least squares for various measures of prices at the country level.[20]

We have conjectured a positive relationship between the size of pass-through and returns on search proxied by the price of a good. The estimates suggest a non-linear relationship. For goods with prices less than approximately $150 (which is close to the median price of goods in our data), the relationship is positive, but it turns into a negative one for more expensive goods. This inverted-U relationship suggests that pass-through and search have an interplay more complex than often assumed. Indeed, pass-through and search are determined simultaneously in equilibrium and firms can respond to endogenous search effort by pricing goods in such a way that returns to search are reduced for expensive goods where search is likely to be most intensive and hence the elasticity of demand can be particularly high. For example, a manufacturer can require online stores to sell its good at a price set by the manufacturer rather than by retailers thus limiting price dispersion and competition between stores. In addition, manufactures could be more likely to sell high-price goods (e.g., laptops) directly to customers than low-price goods (e.g., cables) and they may be interested in preserving sales through their websites again by limiting price dispersion. While we are not able to test hypotheses of this type with our data, there is plenty of anecdotal evidence consistent with this explanation.[21]

Interestingly, we also find an inverted-U relationship between a good's price and the speed of price adjustment where the speed is the slowest for goods priced around $150, a price range where

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[19] While $\hat{\alpha}$ and $\hat{\beta}$ are generated variables, this does not pose an econometric problem for us as the errors in $\hat{\alpha}$ and $\hat{\beta}$ are absorbed into the stochastic error terms on the right hand side of specifications (3) and (4).

[20] When estimating coefficients in Tables 5 and 6, we assign equal weights for all goods. However, the precision of estimates for $\hat{\beta}$ and $\hat{\alpha}$ varies across goods since the number of observations used to estimate $\hat{\beta}$ and $\hat{\alpha}$ varies across goods. Given considerable heterogeneity of $\hat{\beta}$ and $\hat{\alpha}$ estimates, one may want to weigh observations based on the precision of $\hat{\beta}$ and $\hat{\alpha}$. Although using standard errors of $\hat{\beta}$ and $\hat{\alpha}$ may be a natural choice for weights, in finite samples $\hat{\beta}$ and $\hat{\alpha}$ and their standard errors may be correlated (see e.g. Abowd and Card (1989) and Altonji and Segal (1996)) and thus these weights may be inappropriate. A simple alternative is to use the number of observations used in estimation. When we use these as weight, results are similar.

[21] For example, Apple products sold in a broad array of online stores show little if any price dispersion across online stores because Apple apparently coordinates prices across sellers (see an article on zdnet.net).

the estimated pass-through is the highest. Note that $\hat{\alpha}_i$ and $\hat{\beta}_i$ are essentially uncorrelated and, therefore, it is unlikely that this pattern arises mechanically from the way we estimate these parameters. A plausible explanation is likely to stem from incentives to make price adjustments. Intuitively, if pass-through is close to 100 percent, returns to arbitrage are second-order as the profit function is approximately flat. As a result, the speed of price adjustment is slow. In contrast, when pass-through is low, returns to arbitrage are high (the slope of the profit function is steep) and, thus, the speed is fast.

There is also a non-linear relationship between the number of sellers and pricing dynamics. Specifically, raising the number of sellers from two sellers (the minimum number) to 4-5 sellers (approxaimtely, the average number of sellers) is associated with increased pass-through and the speed of price adjustment. Further increases in the number of sellers are associated with decreasing pass- through and the speed of price adjustment.

There is a strong negative relationship between the size of the pass-through and price stickiness. Specifically, a one standard deviation increase in the frequency of price changes (0.32) increases pass-through by about 50 percentage points. Consistent with theoretical predictions, goods with stickier prices have a lower speed of price adjustment.

Greater synchronization of price changes is weakly associated with larger pass-through. A one standard deviation increase in the degree of synchronization (0.167) increases pass-through by 2 to 8 percentage points. At the same time, we find evidence that synchronization decelerates price adjustment. This result suggests that synchronization is likely to indicate market power enabling coordination of price changes and limiting the ability of online sellers to eliminate arbitrage opportunities.

The stability of sellers is significantly negatively correlated with the speed of price adjustment: a lower turnover of sellers (higher stability) reduces the speed (i.e., $\hat{\beta}$ becomes larger and closer to zero). This finding is consistent with the view that easy entry into a market and limited time-horizons for sellers, which limits the scope for collusion, are likely to eliminate arbitrage opportunities and mis-pricing of goods faster. The quantitative effect of seller stability is large. A one standard deviation increase in stability (approximately 0.2) would reduce the speed ($\hat{\beta}$) by about 0.1 which is enough to severely limit convergence to equilibrium.

However, the stability of sellers is also positively correlated with the size of pass-through. Quantitatively this relationship is strong: goods with a stable pool of sellers tend to have a nearly complete pass-through. This surprising result suggests that, while the stability of sellers can proxy for entry costs and thus provide a natural explanation of slower price adjustment for goods with a stable pool of sellers, the stability is also likely to capture other important dimensions of how online markets operate. For example, a stable set of sellers can be associated with increased horizons over which sellers set prices so that they have enough time to eventually respond to movements of the nominal exchange rate. In contrast, a rapidly changing pool of sellers may indicate that online stores focus on short-term factors (e.g., inventory) and thus fail to respond to macroeconomic forces. Another possibility is that increased stability is determined by large inventories held by online sellers, which yields slow price adjustment, and by manufacturers using producer-currency pricing rather than pricing to market, which gives a deep pass-through.

D. Margins of price adjustment

While the previous section documents that pass-through and the speed of price adjustment are high in online markets, one can learn more about these two objects by exploring what margins of price adjustment are used in response to movements in the nominal exchange rate. We use our specification (1) to construct a measure of the deviation from equilibrium EC:

$$\widehat{EC}_{it} = \log\left(\frac{P_{it}^{CA}}{P_{it}^{US}}\right) - \hat{\alpha} EX_t. \qquad (5)$$

where, as before, i and t index goods and time (weeks), P is a measure of a price (e.g., median price, mean price, minimum price), EX is the nominal exchange rate. Note that α is estimated for each price measure separately.

We measure the intensive margin of price adjustment as the average price change (conditional on price change) across sellers of good i in country c and week t:

$$\overline{dP}_{ict} = \frac{\sum_{s=1}^{S_{itc}} \log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) \times \mathbf{1}\left\{\left|\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right)\right| > 0.01\right\}}{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\left|\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right)\right| > 0.01\right\}}. \qquad (6)$$

We also calculate the mean size of price increases and price decreases separately:

$$\overline{dP}_{ict}^{decrease} = \frac{\sum_{s=1}^{S_{itc}} \log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) \times \mathbf{1}\left\{\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) < -0.01\right\}}{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) < -0.01\right\}}, \qquad (6')$$

$$\overline{dP}_{ict}^{increase} = \frac{\sum_{s=1}^{S_{itc}} \log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) \times \mathbf{1}\left\{\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) > 0.01\right\}}{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) > 0.01\right\}}. \qquad (6'')$$

The extensive margin of price adjustment—again with the distinction for any price change, price increase, and price decreases—is measured as

$$\Pr(dP \neq 0)_{ict} = \frac{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\left|\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right)\right| > 0.01\right\}}{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\left|\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right)\right| \text{ is not missing}\right\}} \qquad (7)$$

$$\Pr(dP > 0)_{ict} = \frac{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) > 0.01\right\}}{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\left|\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right)\right| \text{ is not missing}\right\}} \qquad (7')$$

$$\Pr(dP < 0)_{ict} = \frac{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right) < -0.01\right\}}{\sum_{s=1}^{S_{itc}} \mathbf{1}\left\{\left|\log\left(\frac{P_{isct}}{P_{isc,t-1}}\right)\right| \text{ is not missing}\right\}} \qquad (7'')$$

and is thus a fraction of sellers that change their prices in the set of sellers that have listed good i in weeks t and $t-1$.

Finally, stores with the best prices may run out of inventories faster than other stores and thus cheap stores can be more likely to exit the market until they replenish their inventories. We calculate the probability of exit as follows:

$$\Pr(exit)_{ict} = \frac{\sum_{s=1}^{S_{ic,t-1}} \mathbf{1}\{P_{isct} \text{ is missing} \cap P_{isc,t-1} \text{ is not missing}\}}{\sum_{s=1}^{S_{ic,t-1}} \mathbf{1}\{P_{isc,t-1} \text{ is not missing}\}}. \qquad (8)$$

Using these measures, we estimate the following generic specification with a pricing moment given in (6)-(8) as the dependent variable:

$$Moment_{ict} = \gamma_c + \psi_c \widehat{EC}_{i,t-1} + \kappa_{c1} EX_{t-1} + \kappa_{c2} Moment_{ic,t-1} + \lambda_{ic} + error_{ict}. \qquad (9)$$

Note that specification (9) is estimated for each country separately as the direction of the change in the pricing moment can depend on whether equilibrium error EC is positive or negative and thus estimated coefficients may move in opposite directions for Canada and the U.S. For example, if $EC > 0$ (goods in Canada are relatively expensive), one may expect prices in Canada to decrease (i.e., $\overline{dP}_{i,CA,t} < 0$) and prices in the U.S. to increase (i.e., $\overline{dP}_{i,US,t} > 0$) and hence $\psi_{CA} < 0$ and $\psi_{US} > 0$.

Table 7 presents estimates of ψ_c, which is the key parameter in specification (9), for various pricing moments and measures of prices. For the response of the mean price change $\overline{dP}_{ict}$, we find consistently (column 1) that if prices in Canada are 10 percent above equilibrium level, prices in Canada fall by 0.8 to 1.4 percent per week while prices in the U.S. increase by 0.4 to 0.7 percent per week. Consistent with our previous findings, these results suggest fast adjustment of prices to equilibrium levels. This pattern also applies to both price increases (column 2) and price decreases (column 3). For example, if we focus on the mean prices in the U.S. and Canada, a positive equilibrium error EC (i.e., prices are more expensive in Canada), price increases in Canada become smaller while price decreases become larger (more negative). Likewise, a positive equilibrium error EC tends to lead to larger price increases and smaller (i.e., less negative) prices decreases in the U.S. Hence, we do not observe strong asymmetric effects in the size of price adjustment as prices appear to be equality flexible in terms of increases and decreases. The magnitude of the response is generally larger for Canada than for the U.S. which is consistent with the view that price adjustment is likely to be larger in smaller markets.

The frequency of price adjustment for all price changes (column 4) does not exhibit a robust relationship to equilibrium errors. However, this lack of correlation reflects that movements in frequencies of price increases and frequencies of price decreases roughly offset each other. Once we focus on the frequency of price increases (column 5) and the frequency of price decreases (column 6) separately, the data indicates a strong link between the frequencies of price adjustment and equilibrium errors. Consider the frequency of price increases when we use mean prices. A positive 10 percent equilibrium error EC reduces the frequency of prices increases in Canada by 0.79 percent and increases the frequency of price increase in the U.S. by 0.24 percent. This finding is in line with the price adjustments along the intensive margin where positive EC leads to smaller price increases in Canada and larger price increases in the U.S. The effect is in the opposite direction for the frequency of price decreases: a positive 10 percent equilibrium error EC increases the frequency of prices decreases in Canada by 0.77 percent and decreases the frequency of price decrease in the U.S. by 0.16 percent. One can immediately see that since the movements of the frequency of price increases and the frequency of price decreases have similar magnitudes and thus the effect on the frequency of all price changes becomes weak. Similar to the results for the intensive margin, the response of the extensive margin is stronger for Canada than for the U.S.

The exit of goods with cheap prices is not strongly correlated with equilibrium errors. In only one case with minimum prices, we find significant statistical evidence that a positive equilibrium error makes exit of stores less likely in Canada and more likely in the U.S. While one should expect this pattern, we conjecture that we do not find the same patterns for other price measures because the consumer pressure arising from price differentials is likely to be the highest for stores offering lowest prices. Indeed, price sensitive consumers are likely to buy at the cheapest prices and thus are more likely to respond to arbitrage opportunities when relative prices shift. At the same time, given fairly large dispersion of prices within countries, mean or median prices at the level of countries may be too coarse to detect changes in demand arising from shifts in relative prices.

To further explore margins of price adjustment, Figure 5 plots the time series of mean price changes (all price changes, price increases, and price decreases in Panels A, B, and C) when we aggregate across goods (with equal weights) to the country level. We also report the estimated slope from regressing each series on the nominal exchange rate. In general, price increases (decreases) in Canada are negatively (positively) correlated with the nominal exchange rate (CAD/USD) and the pattern of correlations is reversed for the U.S. One can also observe that the correlation between the size of price decreases in the U.S. and in Canada is negative.

In similar spirit, we aggregate frequencies of price adjustment across goods to the country level (Panels D, E, and F). These aggregate frequencies for the U.S. and especially for Canada tend to be positively correlated with the nominal exchange rate. However, a decomposition of price changes into price increases (Panel D) and price decreases (Panel F) suggests that the correlation with the nominal exchange rate is the strongest for price increases in Canada and equally weak for price increases and price decreases in the U.S.

The frequency of price increases and decreases in Canada was the highest in late 2008 and early 2009 when the Canadian dollar was strongly appreciating. The fact that the frequency of price changes rose for both price increases and price decreases highlights that the exchange rate movements induced firms to review their prices with possible adjustment in either direction rather than move all Canadian prices in one direction. In other words, firms appeared to be re-optimizing their prices rather than mechanically adjusting their prices by changes in the exchange rate. Obviously, these price adjustments happened during the Great Recession, so perhaps this "churning" of price changes reflects increased intensity of price adjustment in recessions rather than responsiveness of prices to exchange rate fluctuations. However, we observe only a moderate to weak increase in the frequency of price adjustment for U.S. retailers and therefore it is hard to see the contribution of the Great Recession to increased frequency of price adjustment in Canada.

To explore this issue further, we regress the frequency of price increases and the frequency of price decreases on the CAD/USD exchange rate over the period that excludes the Great Recession; that is, we use data after June 2009. We find that the frequency of price decreases in Canada is not statistically or economically sensitive to the exchange rate while the frequency of price increases continues to stay highly significant in statistical and economic terms. At the same time, the frequency of price decreases in the U.S. is positively related to the CAD/USD exchange rate (although the sensitivity is smaller than that for Canada) while the frequency of price increases in the U.S. does not exhibit a significant correlation with the exchange rate. This pattern of responses is consistent with the predictions of economic theory on how firms should adjust their prices and therefore it corroborates our findings in Table 7.

The exit frequency (Figure 6) is positively correlated with the nominal exchange rate for both the U.S. and Canada but, similar to other margins, the exit margin in Canada is more sensitive to fluctuations in the nominal exchange rate. Some of the positive correlation is determined by the coincidence of high turnover of sellers and goods (i.e., high exit frequency) and depreciation of the Canadian dollar in the Great Recession. If we exclude the Great Recession, the exit frequency in the U.S. shows no sensitivity to the exchange rate, while the exit frequency in Canada is even more strongly positively related to the CAD/USD exchange rate. It appears that, when the Canadian dollar depreciates, the U.S. consumers take advantage of cheap Canadian prices and deplete inventories of Canadian stores while the pool of Canadian customers is unable to exercise the same pressure on U.S. stores when the Canadian dollar appreciates.

5. Concluding remarks

While the law of one price is an appealing concept, the vast majority of previous research has emphasized various frictions that prevent the law from holding over relative long periods. These frictions can take a variety of forms but the most popular barriers leading to violations of the law are search costs, costs of nominal price adjustment, and transportation costs. Assessing the contribution of these frictions has been remarkably difficult as these frictions are ubiquitous in standard markets with brick-and-mortar stores.

Online markets have unusual characteristics such as low search costs, irrelevance of physical locations of buyers and sellers, and negligible physical costs of price changes. Thus, studying price setting in online markets offers a unique opportunity to rule out the prominent frictions and explore whether the law of one price holds in this close to ideal setting.

We construct a new, massive dataset of online price quotes in the U.S. and Canada. This dataset has a number of desirable features such as long time series, large cross sections, and multiple sellers. We document that, relative to prices in regular stores, prices in online markets are more flexible as well as exhibit stronger pass-through and faster convergence in response to movements of the nominal exchange rate. Multiple margins of adjustment (frequency of price changes, direction of price changes, size of price changes, exit of sellers) are active in the process of responding to nominal exchange rate shocks. Furthermore, we use the richness of our dataset to show that the sensitivity of prices to changes in the nominal exchange rate can be systematically related to the fundamental characteristics of goods and markets (e.g., the degree of competition). To the extent future retail will shift to the internet, one can therefore expect that cross-country price differentials are going to be smaller and less persistent, bringing the law of one price closer to reality.

We also demonstrate that online markets do have imperfections. For example, a large cross-sectional dispersion of prices for identical goods and incomplete pass-through for some types of goods appear inconsistent with the notion of an ideal marketplace. What prevents internet shopping from being frictionless is an open question. Perhaps, consumers and firms have significant informational frictions. For example, consumers may prefer to buy goods from a fixed store because this "habit" saves them time by not having to learn the details of how transactions are processed by alternative sellers (e.g., shipping time and cost, return policy, accepted means of payment). In a similar spirit, online stores may be overwhelmed with information flows and thus may resort to using simple rules and periodic reviews to economize on costs of processing information. We hope that future research will shed more light on why imperfections may persist in online markets.

This paper has a number of implications for data collection. For example, the Bureau of Labor Statistics and other statistical agencies should sample online prices at higher frequencies since these prices are more flexible and responsive to shocks. There is a distribution of prices even for precisely defined goods and, therefore, statistical agencies should sample prices from multiple stores to ensure that one can construct a good measure of transaction prices. Scraping of online prices is a cheap and fast approach to collect price quotes but scraping cannot provide a measure of quantities. Using the number of clicks may provide a simple proxy for quantities of goods sold in online stores, but the quality of this and similar proxies should be verified with alternative information.

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Figure 1. Screenshots of typical web-pages from price comparison websites.

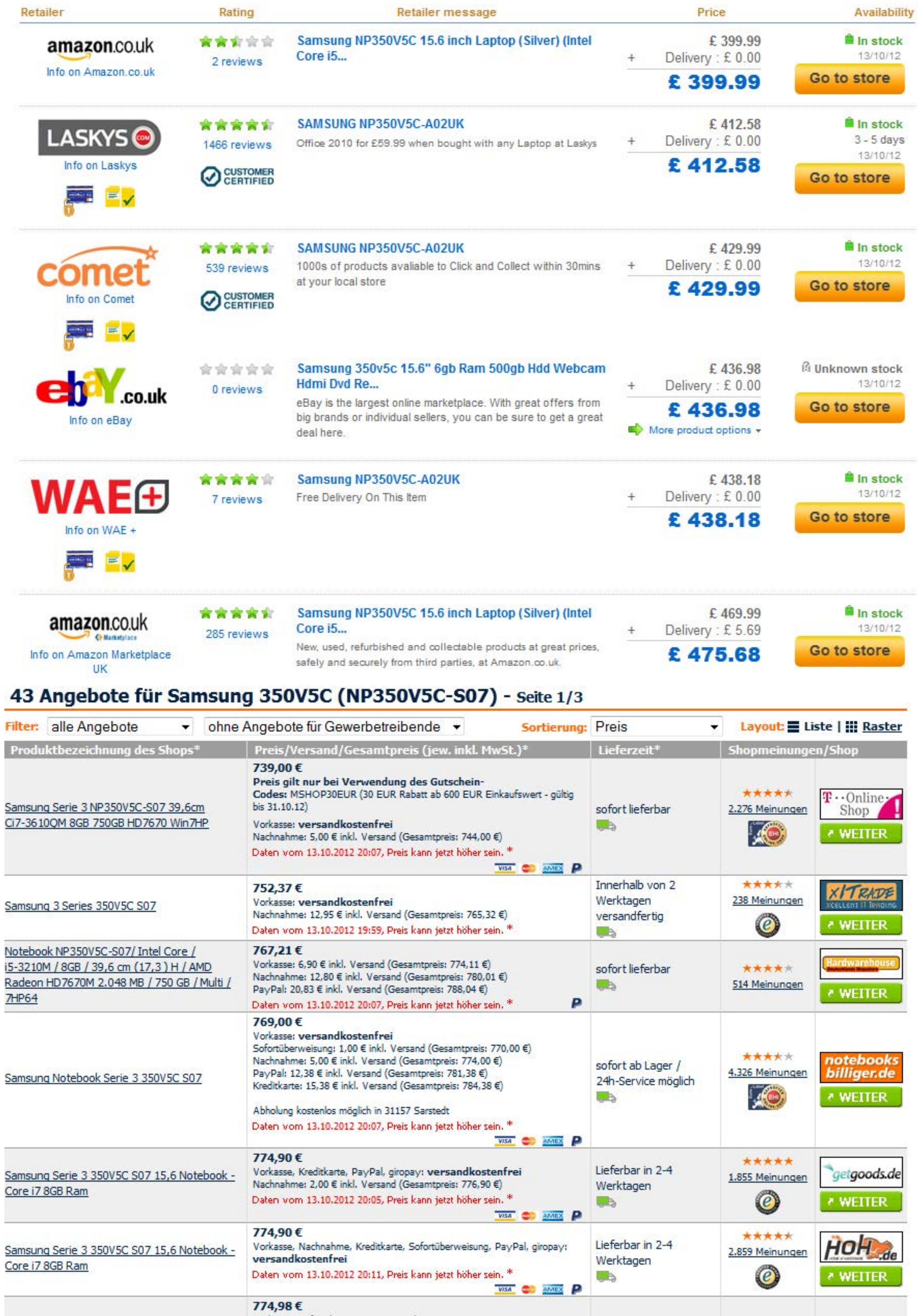
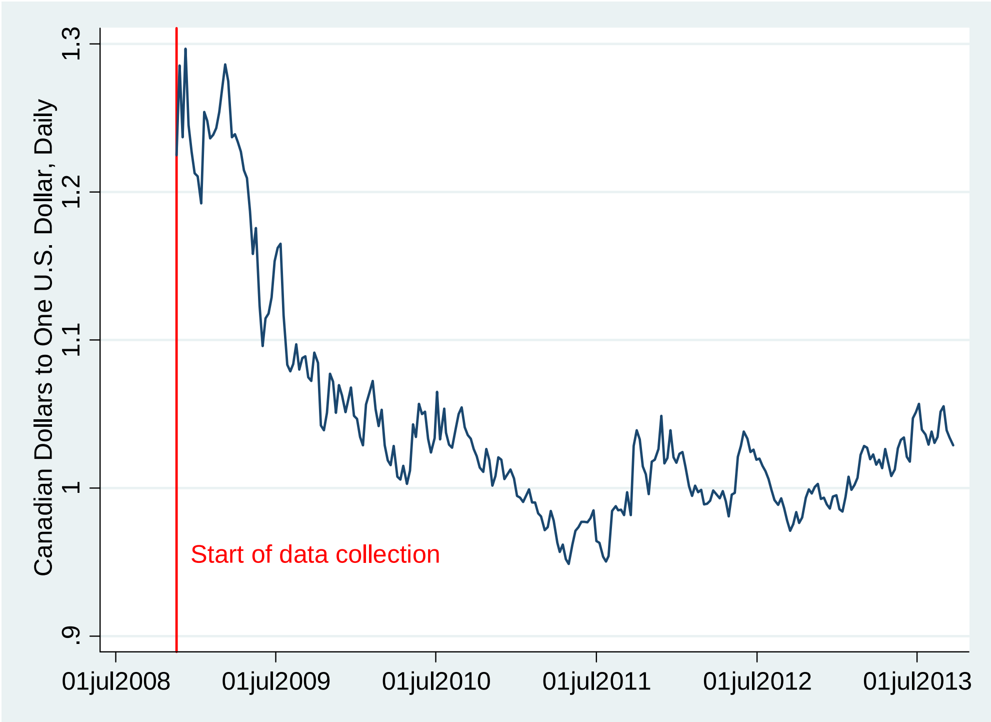
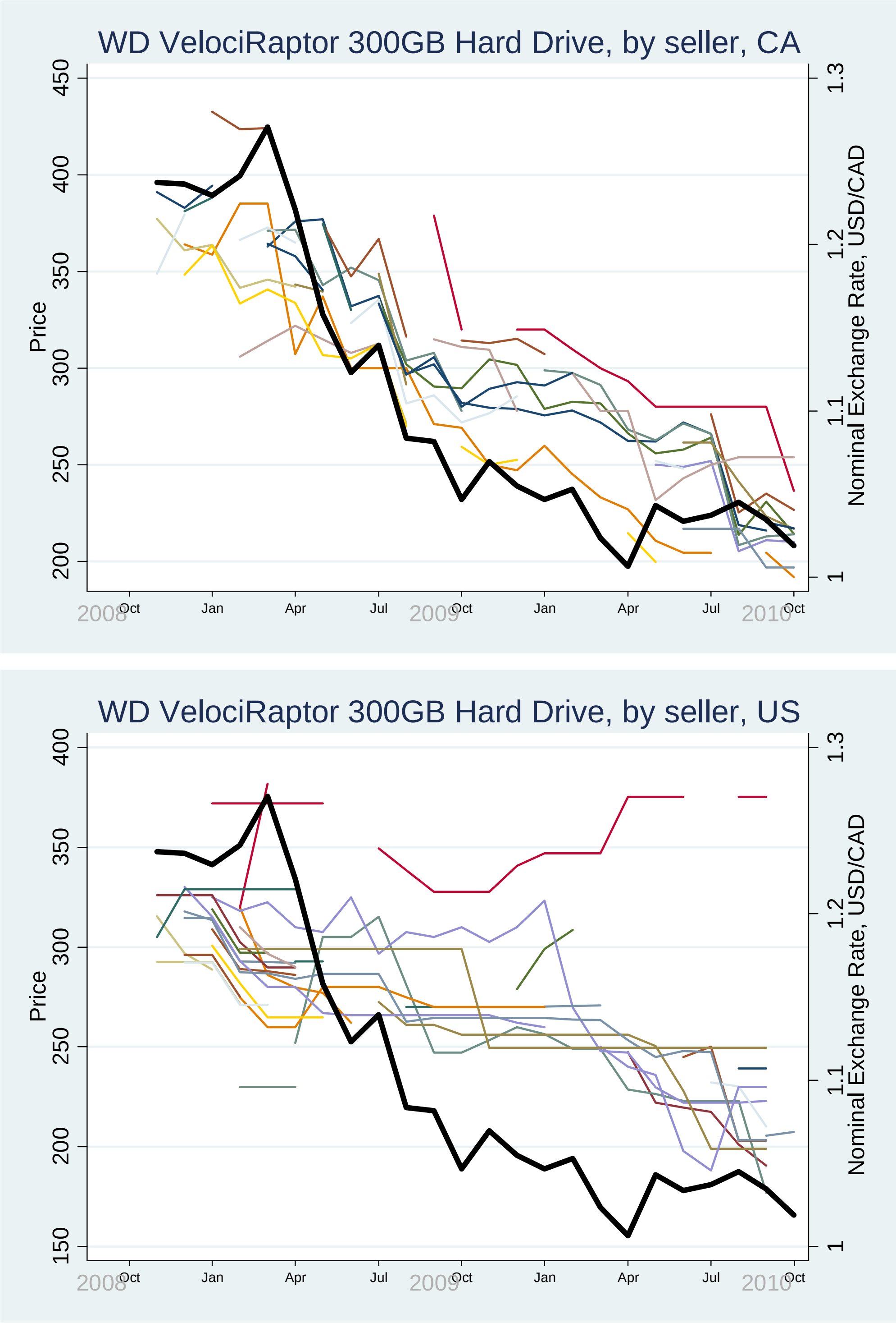


Figure 2. Time series of CAD/USD exchange rate.



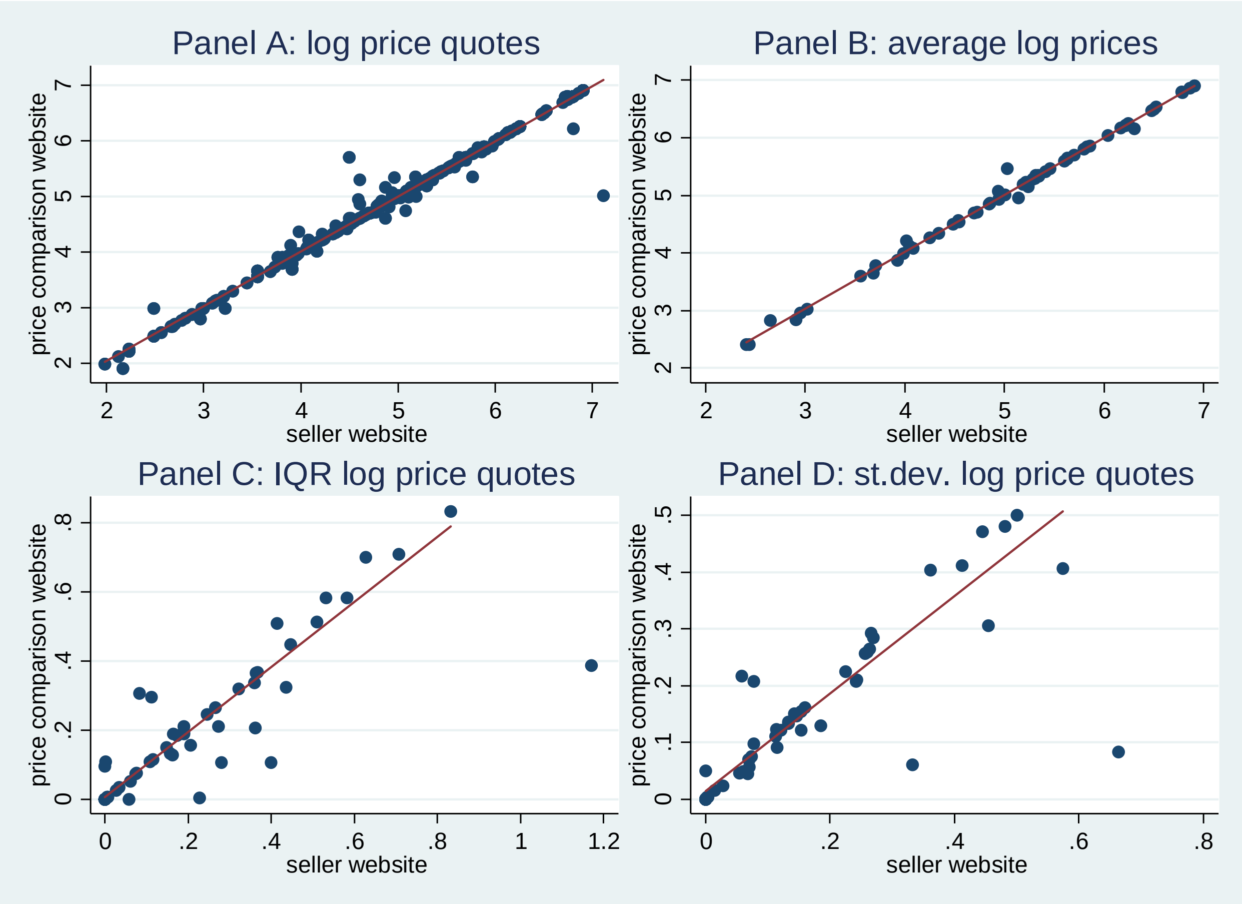
Notes: Source: Board of Governors.

Figure 3. Price quotes.



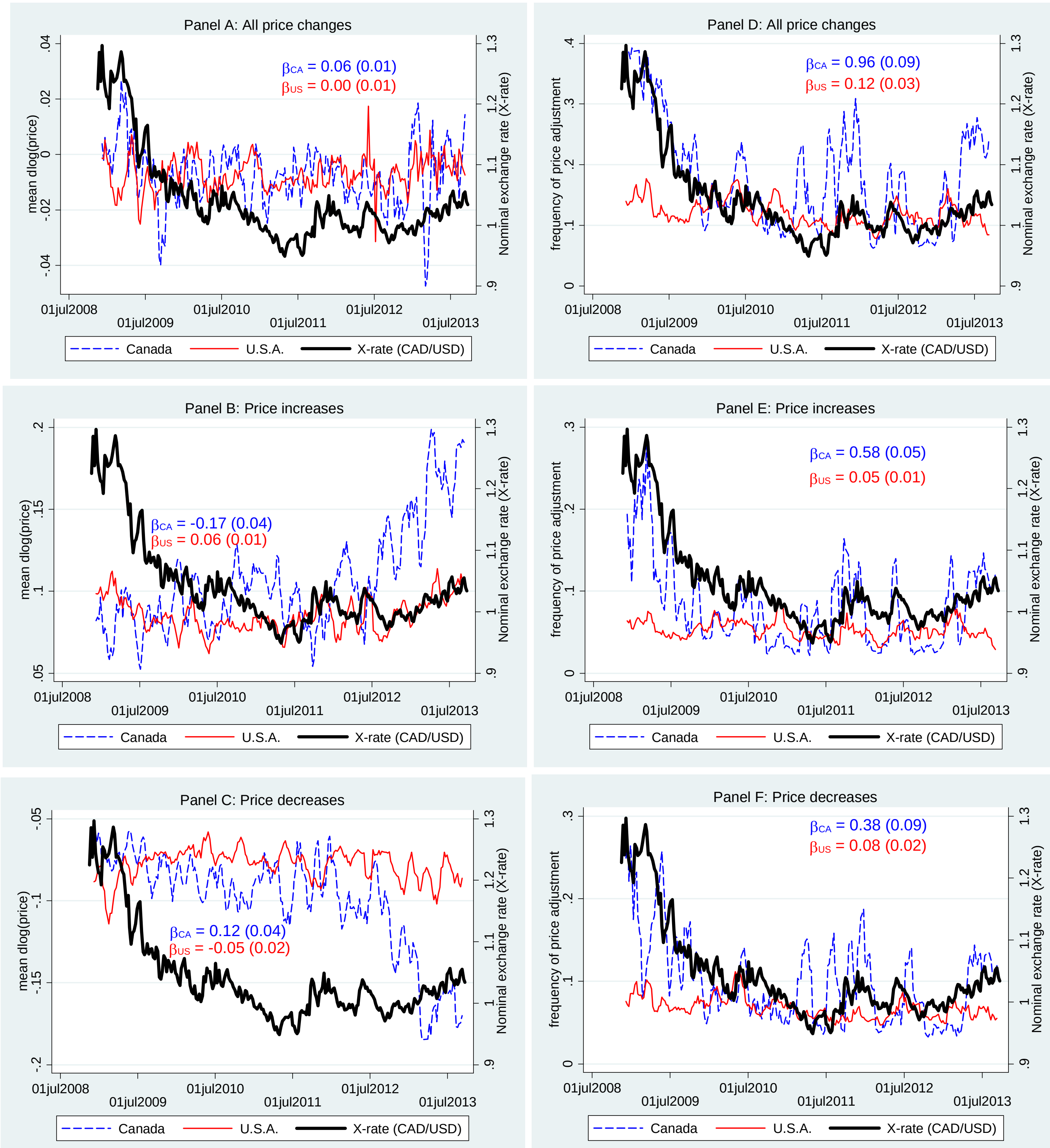
Notes: Solid, thick black line is the nominal exchange rate. All other lines are price quotes for the WD VelociRaptor 300Gb hard drive.

Figure 4. Price quotes listed on the price comparison website and seller websites.



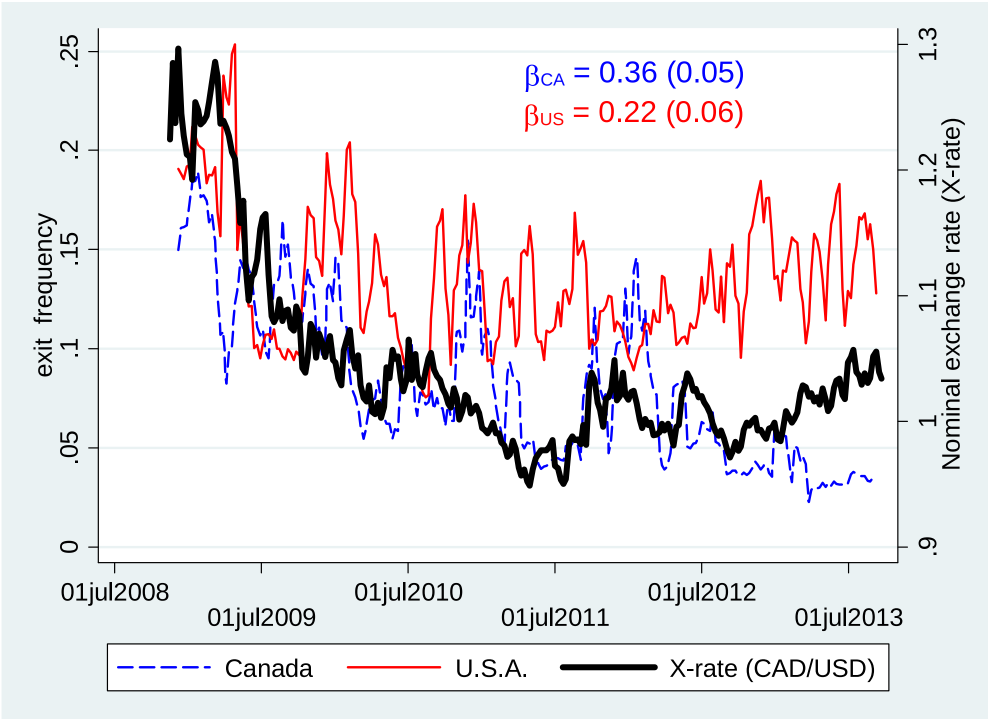
Notes: Panel A shows price quotes listed on the price comparison website and seller websites for each good, that is, each point is a good-seller price quote. In Panel B, average log price quote is calculated for each source of price information, that is, each point shows an average log price for a good. Panel C shows the interquantile range of log prices across sellers for each good in both sources of price information. Panel D shows the standard deviation of log prices across sellers for each good in both sources of price information.

Figure 5. Intensive and extensive margins of price adjustment.



Notes: β_{CA} and β_{US} show estimated slopes of regressing a given variable for Canada and the U.S. on the nominal CAD/USD exchange rate. Newey-West standard errors are in parentheses. See section 5.D for further details.

Figure 6. Exit margin of price adjustment.



Notes: β_{CA} and β_{US} show estimated slopes of regressing a given variable for Canada and the U.S. on the nominal exchange rate. Newey-West standard errors are in parentheses. See section 5.D for further details.

Table 1. Description of categories.

Category	Type
Cameras (10 categories)	35mm SLR lens Accessories, Bags and Cases, Binoculars, Camcorders, Camcorder Batteries, Camcorder Accessories, Dedicated Flashes, Digital Cameras, SLR Lenses, Tripods
Computers (20 categories)	Cases, Desktops, Flash Memory, Flat Panel LCD monitors, Hard Drives, Hubs, Keyboards, Laptop, Laptop Memory, Microphones and Headsets, Modems, Motherboards, Network Adapters, Power Supply, Processors, Scanners, Speakers, Storage Media, UPSS, Webcams
Electronics (13 categories)	Audio Cables, AV Accessories, Calculators, Cash Registers, GPS, Headphones, MP3 players, Portable Device Accessories, Projectors, Projection Screens, Plasma/LCD TV, TV Accessories, Video Cables
Software (12 categories)	Anti-Virus, Audio/Video Utilities, Computer Games, Engineering and Design, Databases, Financial and Legal Software, Graphics and Publishing, Office Suites, Programming, Security, System Utilities, Windows Operating Systems

Table 2. Descriptive statistics.

	Mean (1)	St.Dev (2)	Median (3)	P25 (4)	P75 (5)
Panel A: Canada					
Cross-sectional distribution of prices					
St.dev. log(Price)	0.128	0.105	0.103	0.057	0.162
IQR log(Price)	0.095	0.097	0.067	0.024	0.141
Median log(Price)	5.077	1.488	5.011	3.994	6.113
Median duration of price spell (weeks)					
procedure A	1.350	1.657	1.000	1.000	1.000
procedure B	1.731	2.309	1.000	1.000	2.000
procedure C	2.974	9.615	1.000	1.000	2.000
Frequency of price changes	0.324	0.210	0.285	0.163	0.456
Size of price changes					
Median dlog(Price)	-0.007	0.030	-0.004	-0.009	-0.002
Median abs(dlog(Price))	0.041	0.058	0.022	0.014	0.044
Synchronization of price changes	0.299	0.213	0.272	0.132	0.456
Properties of sellers					
Number of sellers	2.399	1.318	2.037	1.304	3.213
Stability	0.423	0.213	0.360	0.283	0.500
Panel B: USA					
Cross-sectional distribution of prices					
St.dev. log(Price)	0.151	0.123	0.115	0.069	0.195
IQR log(Price)	0.160	0.151	0.115	0.065	0.205
Median log(Price)	4.979	1.471	4.912	3.906	5.999
Median duration of price spell (weeks)					
procedure A	1.487	1.504	1.000	1.000	2.000
procedure B	2.079	2.470	2.000	1.000	2.000
procedure C	4.112	9.335	2.000	1.500	3.000
Frequency of price changes	0.191	0.114	0.179	0.106	0.263
Size of price changes					
Median dlog(Price)	-0.005	0.031	-0.003	-0.010	0.001
Median abs(dlog(Price))	0.042	0.048	0.030	0.017	0.051
Synchronization of price changes	0.190	0.121	0.176	0.109	0.252
Properties of sellers					
Number of sellers	3.627	1.983	3.276	2.186	4.569
Stability	0.405	0.188	0.366	0.263	0.507

Notes: The number of goods is 12,657.

Table 3. International Price Differentials

	Mean	St.Dev	Median	P25	P75	AR1 OLS	AR1 Type FE	AR1 Good FE	N
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Mean prices									
Relative exchange rate	0.083	0.236	0.062	-0.030	0.199	0.923	0.918	0.816	1,709,011
Real exchange rate	0.052	0.231	0.035	-0.051	0.150	0.917	0.912	0.806	1,709,011
Panel B: Median prices									
Relative exchange rate	0.088	0.238	0.065	-0.025	0.204	0.913	0.908	0.801	1,708,982
Real exchange rate	0.057	0.233	0.038	-0.045	0.154	0.907	0.902	0.790	1,708,982
Panel C: Minimum prices									
Relative exchange rate	0.133	0.279	0.096	-0.003	0.255	0.912	0.906	0.801	1,708,960
Real exchange rate	0.102	0.276	0.070	-0.029	0.219	0.909	0.903	0.795	1,708,960
Panel D: Star-weighted prices (imputation A, missing = 1)									
Relative exchange rate	0.080	0.278	0.069	-0.035	0.210	0.919	0.914	0.834	1,708,969
Real exchange rate	0.049	0.275	0.040	-0.061	0.167	0.916	0.911	0.830	1,708,969
Panel E: Star-weighted prices (imputation B, missing = 2.5)									
Relative exchange rate	0.073	0.274	0.062	-0.040	0.200	0.920	0.916	0.836	1,708,979
Real exchange rate	0.042	0.271	0.036	-0.059	0.154	0.917	0.913	0.832	1,708,979

Notes: Relative exchange rate is calculated as $\log\left(P_{it}^{CA}/P_{it}^{US}\right)$ where *i* and *t* index goods and weeks. The real exchange rate is calculated as $\log\left({EX_t}^{-1} \times P_{it}^{CA}/P_{it}^{US}\right)$ where EX_t is the nominal CAD/USD exchange rate. P25 and P75 in columns (4) and (5) show 25th and 75th percentile of the statistics indicated in the first column. Column (6) shows the AR(1) coefficient estimated on the pooled sample. Column (7) shows the AR(1) coefficient estimated on the pooled sample with category fixed effects. Column (8) shows the AR(1) coefficient estimated on the pooled sample with good fixed effects. The sample of goods is the same as in Table 2. See text for further details.

Table 4. Pass-through and speed of price adjustment.

	No Fixed effects	Type Fixed effects	Good Fixed effects	N
	(1)	(2)	(3)	(4)
Panel A: Pass-through				
Mean Price	0.761***	0.736***	0.698***	1,709,011
	(0.105)	(0.096)	(0.080)	
Median Price	0.743***	0.719***	0.698***	1,708,982
	(0.106)	(0.097)	(0.082)	
Minimum Price	0.667***	0.669***	0.677***	1,708,960
	(0.067)	(0.056)	(0.042)	
Star-weighted Price (missing = 1)	0.676***	0.634***	0.614***	1,708,969
	(0.098)	(0.088)	(0.077)	
Star-weighted Price (missing = 2.5)	0.691***	0.668***	0.642***	1,708,979
	(0.089)	(0.082)	(0.071)	
Panel B: Speed of Adjustment				
Mean Price	-0.060***	-0.064***	-0.158***	885,150
	(0.004)	(0.004)	(0.005)	
Median Price	-0.067***	-0.072***	-0.170***	884,835
	(0.004)	(0.003)	(0.005)	
Minimum Price	-0.067***	-0.072***	-0.169***	883,912
	(0.003)	(0.003)	(0.005)	
Star-weighted Price (missing = 1)	-0.062***	-0.066***	-0.135***	886,115
	(0.007)	(0.007)	(0.012)	
Star-weighted Price (missing = 2.5)	-0.061***	-0.064***	-0.133***	886,292
	(0.007)	(0.007)	(0.012)	
Panel C: Intra-seller prices				
Pass-through	0.905***	0.627***	0.284***	118,680
	(0.029)	(0.080)	(0.050)	
Speed of Adjustment	-0.000	-0.046***	-0.116***	54,795
	(0.005)	(0.009)	(0.013)	

Notes: Panel A presents estimates of α in specification (1). Panel B presents estimates of β in specification (2). Panel C reports estimates of α (the first row) and β (the second row) for the sample of price quotes by the same seller in the U.S. and Canada. Driscoll and Kraay (1998) standard errors are in parentheses. ***, **, * show statistical significance at the 1%, 5% and 10% levels.

Table 5. Descriptive statistics of estimated pass-through and speed of price adjustment by good.

Price measure	Variable	Mean	St.Dev.	Median	P25	P75
Mean Price	β	-0.214	0.222	-0.159	-0.298	-0.069
	α	0.616	2.218	0.698	-0.192	1.460
Median Price	β	-0.232	0.232	-0.175	-0.326	-0.076
	α	0.647	2.253	0.719	-0.164	1.469
Minimum Price	β	-0.229	0.236	-0.170	-0.322	-0.071
	α	0.632	2.568	0.716	-0.265	1.609
Star-weighted Price	β	-0.219	0.244	-0.162	-0.306	-0.069
(missing = 1)	α	0.558	2.512	0.666	-0.205	1.459
Star-weighted Price	β	-0.215	0.247	-0.158	-0.298	-0.067
(missing = 2.5)	α	0.544	2.490	0.675	-0.206	1.448

Notes: The table shows moments of $\hat{\alpha}$ and $\hat{\beta}$ estimated for each good separately. The last two columns show 25th and 75th percentiles. The number of goods is 12,657.

Table 6. Determinants of pass-through and speed of price adjustment.

Regressors	Price measure				
	Mean price	Median price	Minimum price	Star-weighted Price (missing = 1)	Star-weighted Price (missing = 2.5)
	(1)	(2)	(3)	(4)	(5)
Panel A: Pass Through					
Log(Median Price)	0.154*	0.260***	0.546***	-0.074	0.072
	(0.092)	(0.097)	(0.124)	(0.143)	(0.104)
Log(Median Price)^2	-0.020**	-0.028***	-0.054***	0.000	-0.012
	(0.008)	(0.008)	(0.011)	(0.012)	(0.009)
Freq. of price change	1.511***	1.515***	1.882***	1.525***	1.537***
	(0.172)	(0.155)	(0.236)	(0.155)	(0.153)
Log(Sellers)	1.435***	1.563***	2.152***	1.673***	1.535***
	(0.317)	(0.348)	(0.400)	(0.348)	(0.338)
Log(Sellers)^2	-0.441***	-0.469***	-0.666***	-0.528***	-0.470***
	(0.092)	(0.099)	(0.123)	(0.100)	(0.098)
Stability of Sellers	0.677**	0.851**	0.903**	0.138	0.329
	(0.329)	(0.365)	(0.398)	(0.305)	(0.308)
Synchronization	-0.024	-0.140	-0.474*	-0.189	-0.130
	(0.255)	(0.262)	(0.265)	(0.221)	(0.234)
Average Reputation	0.039	0.040	0.139**	0.046	0.032
	(0.047)	(0.048)	(0.053)	(0.046)	(0.046)
Observations	11,747	11,731	11,713	11,749	11,750
R2	0.09	0.09	0.11	0.09	0.09
Panel B: Speed of Adjustment					
Log(Median Price)	0.033***	0.041***	0.007	0.022**	0.025**
	(0.011)	(0.012)	(0.010)	(0.010)	(0.011)
Log(Median Price)^2	-0.003***	-0.004***	-0.001	-0.002**	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Freq. of price change	-0.079***	-0.092***	-0.073***	-0.079***	-0.087***
	(0.022)	(0.020)	(0.026)	(0.021)	(0.021)
Log(Sellers)	-0.173***	-0.156***	-0.147**	-0.169***	-0.167***
	(0.054)	(0.053)	(0.060)	(0.057)	(0.057)
Log(Sellers)^2	0.054***	0.047***	0.044**	0.053***	0.052***
	(0.017)	(0.017)	(0.018)	(0.018)	(0.018)
Stability of Sellers	0.280***	0.385***	0.337***	0.282***	0.261***
	(0.071)	(0.072)	(0.052)	(0.067)	(0.071)
Synchronization	0.059***	0.047*	0.039	0.075***	0.075***
	(0.022)	(0.025)	(0.028)	(0.024)	(0.022)
Average Reputation	-0.003	-0.005	-0.005	-0.000	-0.002
	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Observations	11,743	11,724	11,713	11,740	11,741
R2	0.13	0.12	0.13	0.13	0.13

Notes: Panels A and B report estimated specifications (3) and (4) respectively. Category fixed effects C_i and time fixed effects T_i are included but not reported. The regressions are run on samples where top and bottom 2 percent of estimated α and β are truncated. Standard errors are clustered by good type. ***, **, * show statistical significance at the 1%, 5% and 10% levels.

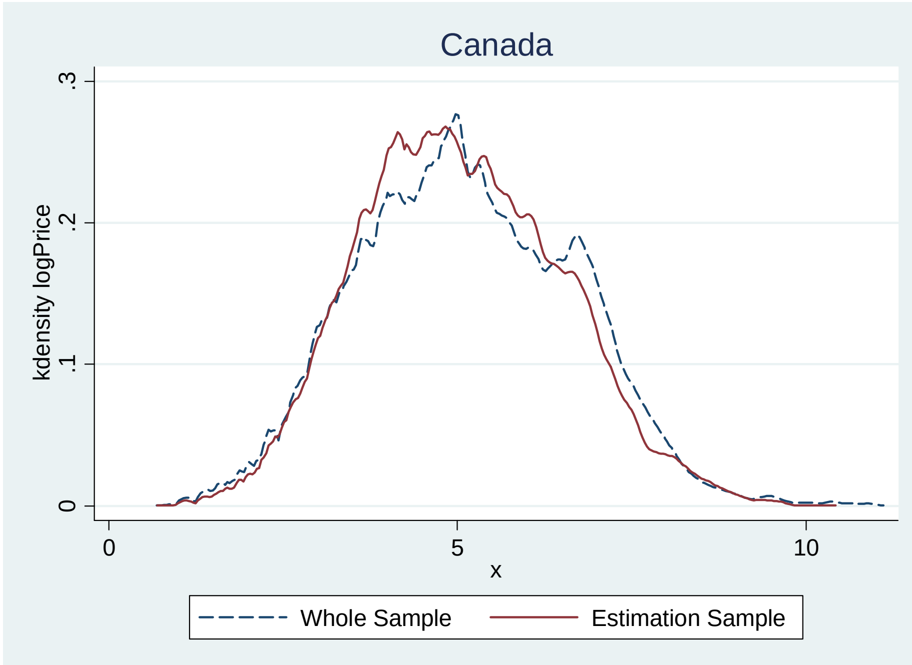
Table 7. Margins of price adjustment

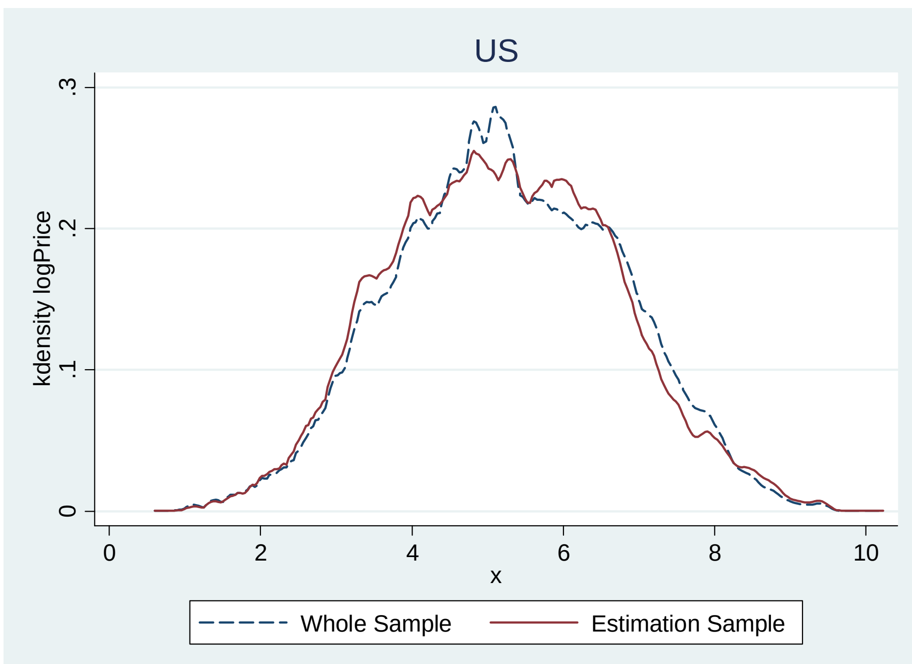
		Mean price change			Probability of price adjustment			Probability of exit
		Any	Increase	Decrease	Any	Increase	Decrease	
		$\overline{dP}_{ict}$	$\overline{dP}_{ict}^{increase}$	$\overline{dP}_{ict}^{decrease}$	$\Pr(dP \neq 0)$	$\Pr(dP > 0)$	$\Pr(dP < 0)$	$\Pr(exit)$
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mean price	CA	-0.137***	-0.048***	-0.091***	-0.002	-0.079***	0.077***	-0.010
		(0.016)	(0.014)	(0.010)	(0.014)	(0.009)	(0.012)	(0.007)
	US	0.067***	0.042***	0.050***	0.008	0.024***	-0.016***	-0.006
		(0.007)	(0.008)	(0.006)	(0.006)	(0.005)	(0.004)	(0.008)
Median price	CA	-0.113***	-0.030***	-0.072***	-0.001	-0.074***	0.072***	-0.010
		(0.015)	(0.013)	(0.009)	(0.013)	(0.008)	(0.012)	(0.006)
	US	0.058***	0.026***	0.047***	0.004	0.023***	-0.019***	-0.003
		(0.006)	(0.007)	(0.006)	(0.006)	(0.005)	(0.004)	(0.007)
Minimum Price	CA	-0.080***	-0.038***	-0.053***	-0.011	-0.052***	0.042***	-0.043***
		(0.010)	(0.006)	(0.008)	(0.011)	(0.005)	(0.010)	(0.004)
	US	0.038***	0.059***	0.002	0.009***	0.020***	-0.011***	0.027***
		(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.002)	(0.004)
Star-weighted Price (missing = 1)	CA	-0.086***	-0.034***	-0.055***	-0.009	-0.049***	0.040***	-0.001
		(0.015)	(0.011)	(0.010)	(0.009)	(0.010)	(0.008)	(0.004)
	US	0.036***	0.014***	0.035***	0.007*	0.015***	-0.008***	-0.002
		(0.007)	(0.005)	(0.006)	(0.004)	(0.004)	(0.003)	(0.003)
Star-weighted Price (missing = 2.5)	CA	-0.092***	-0.035***	-0.060***	-0.005	-0.048***	0.043***	-0.001
		(0.017)	(0.012)	(0.011)	(0.009)	(0.010)	(0.009)	(0.004)
	US	0.037***	0.016***	0.036***	0.007*	0.015***	-0.008***	-0.004
		(0.007)	(0.005)	(0.006)	(0.004)	(0.004)	(0.002)	(0.004)

Notes: The table reports estimated ψ in specification (9). Good fixed effects are included but not reported. Newey-West standard errors are in parentheses. ***, **, * show statistical significance at the 1%, 5% and 10% levels.

APPENDIX

Appendix Figure 1. Distribution of prices in the full and estimation samples.





Notes: The figures show kernel densities for the distribution of prices (Epanechnikov kernel with optimal width). Log price is on the horizontal axis.

Appendix Table 1. Pricing moments for the full and estimation sample.

Moment	U.S.A.		Canada	
	Estimation sample	Full sample	Estimation sample	Full sample
	(1)	(2)	(3)	(4)
Mean price	5.20	5.27	5.04	5.13
Average cross-sectional st.dev. log price	0.16	0.16	0.12	0.12
Average freq. of price changes	0.21	0.19	0.34	0.34
Average absolute size of price change	0.05	0.06	0.05	0.05
Average turnover of sellers	0.90	0.91	0.89	0.92
Average seller rating	3.06	3.08	2.60	2.70
Number of sellers	5.95	5.36	4.10	3.26

Appendix Table 2. Descriptive statistics for gross prices that include taxes and shipping costs.

	Mean	St.Dev.	Median	P25	P75	AR1 OLS	AR1 Type FE	AR1 Good FE	N
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Mean prices									
Relative exchange rate	0.107	0.205	0.097	0.006	0.180	0.929	0.922	0.738	830,169
Real exchange rate	0.064	0.205	0.052	-0.038	0.138	0.928	0.921	0.741	830,169
Panel B: Median prices									
Relative exchange rate	0.109	0.205	0.098	0.009	0.181	0.919	0.911	0.719	830,167
Real exchange rate	0.065	0.206	0.053	-0.036	0.141	0.918	0.911	0.724	830,167
Panel C: Minimum prices									
Relative exchange rate	0.166	0.253	0.135	0.020	0.284	0.920	0.912	0.731	830,216
Real exchange rate	0.123	0.255	0.095	-0.026	0.237	0.920	0.913	0.742	830,216
Panel D: Star-weighted prices (imputation A, missing = 1)									
Relative exchange rate	0.117	0.210	0.090	0.006	0.222	0.933	0.927	0.745	830,180
Real exchange rate	0.073	0.211	0.047	-0.040	0.176	0.932	0.926	0.747	830,180
Panel E: Star-weighted prices (imputation B, missing = 2.5)									
Relative exchange rate	0.108	0.205	0.086	0.009	0.193	0.933	0.926	0.743	830,127
Real exchange rate	0.064	0.205	0.042	-0.035	0.154	0.931	0.925	0.745	830,127

Notes: Relative exchange rate is calculated as $\log\left(P_{it}^{CA}/P_{it}^{US}\right)$ where *i* and *t* index goods and weeks. The real exchange rate is calculated as $\log\left({EX_t}^{-1} \times P_{it}^{CA}/P_{it}^{US}\right)$ where EX_t is the nominal CAD/USD exchange rate. P25 and P75 in columns (4) and (5) show 25th and 75th percentile of the statistics indicated in the first column. Column (6) shows the AR(1) coefficient estimated on the pooled sample. Column (7) shows the AR(1) coefficient estimated on the pooled sample with category fixed effects. Column (8) shows the AR(1) coefficient estimated on the pooled sample with good fixed effects. The sample of goods is the same as in Table 2. See text for further details.

Appendix Table 3. Pass-through and speed of price adjustment for gross and net prices.

	Panel A: Pass-through			
	Gross Prices		Net Prices	
	Good Fixed effects	N	Good Fixed effects	N
	(3)	(4)	(3)	(4)
Mean Price	0.166	481,719	0.212*	481,710
	(0.105)		(0.111)	
Median Price	0.201**	481,716	0.253**	481,652
	(0.096)		(0.100)	
Minimum Price	0.126	480,759	0.169*	480,691
	(0.091)		(0.085)	
Star-weighted Price (missing = 1)	0.428***	481,669	0.454***	481,690
	(0.098)		(0.100)	
Star-weighted Price (missing = 2.5)	0.252**	481,739	0.291**	481,724
	(0.106)		(0.111)	

	Panel B: Speed of Adjustment			
	Gross Prices		Net Prices	
	Good Fixed effects	N	Good Fixed effects	N
	(1)	(2)	(3)	(4)
Mean Price	-0.216***	335,958	-0.210***	336,010
	(0.010)		(0.010)	
Median Price	-0.235***	335,801	-0.228***	335,806
	(0.009)		(0.009)	
Minimum Price	-0.235***	334,773	-0.231***	334,710
	(0.011)		(0.010)	
Star-weighted Price (missing = 1)	-0.216***	335,768	-0.209***	335,834
	(0.009)		(0.009)	
Star-weighted Price (missing = 2.5)	-0.213***	335,942	-0.206***	335,969
	(0.009)		(0.009)	

Notes: The table presents estimates of pass-through and the speed of price adjustment for gross prices (net price + shipping/handling costs) in column (1). The specification reported in the table corresponds to column (3) in Table 4. Column (3) presents results for net prices where the estimation sample of goods is identical to the sample in column (1). All data are at weekly frequency. Driscoll and Kraay (1998) standard errors are in parentheses. ***, **, * show statistical significance at the 1%, 5% and 10% levels.

Appendix Table 4. Pass-through and the speed of price adjustment for gross and net prices, monthly frequency.

	Panel A: Pass-through			
	Gross Prices		Net Prices	
	Good Fixed effects	N	Good Fixed effects	N
	(3)	(4)	(3)	(4)
Mean Price	0.399**	140,385	0.446**	140,356
	(0.160)		(0.161)	
Median Price	0.437***	140,369	0.485***	140,360
	(0.150)		(0.149)	
Minimum Price	0.071	140,055	0.133	140,031
	(0.146)		(0.131)	
Star-weighted Price (missing = 1)	0.672***	140,348	0.692***	140,358
	(0.158)		(0.155)	
Star-weighted Price (missing = 2.5)	0.507***	140,396	0.544***	140,386
	(0.166)		(0.168)	

	Panel B: Speed of Adjustment			
	Gross Prices		Net Prices	
	Good Fixed effects	N	Good Fixed effects	N
	(1)	(2)	(3)	(4)
Mean Price	-0.381***	111,610	-0.366***	111,568
	(0.035)		(0.035)	
Median Price	-0.423***	111,535	-0.406***	111,531
	(0.036)		(0.033)	
Minimum Price	-0.422***	111,027	-0.417***	110,993
	(0.038)		(0.038)	
Star-weighted Price (missing = 1)	-0.397***	111,531	-0.381***	111,523
	(0.031)		(0.031)	
Star-weighted Price (missing = 2.5)	-0.382***	111,617	-0.363***	111,572
	(0.033)		(0.034)	

Notes: The table replicates results of Appendix Table 2 on data aggregated to monthly frequency (instead of weekly). See notes to Appendix Table 2 for more details.

Appendix Table 5. Pass-through and speed of price adjustment, net prices, monthly frequency.

	No Fixed effects	Type Fixed effects	Good Fixed effects	N
	(1)	(2)	(3)	(4)
Panel A: Pass-through				
Mean Price	0.788***	0.773***	0.754***	309,328
	(0.154)	(0.141)	(0.123)	
Median Price	0.760***	0.755***	0.748***	309,303
	(0.151)	(0.141)	(0.127)	
Minimum Price	0.600***	0.612***	0.664***	308,629
	(0.077)	(0.061)	(0.050)	
Star-weighted Price (missing = 1)	0.621***	0.643***	0.627***	309,289
	(0.128)	(0.128)	(0.112)	
Star-weighted Price (missing = 2.5)	0.684***	0.699***	0.680***	309,336
	(0.118)	(0.120)	(0.101)	
Panel B: Speed of Adjustment				
Mean Price	-0.098***	-0.106***	-0.257***	248,077
	(0.012)	(0.012)	(0.012)	
Median Price	-0.113***	-0.121***	-0.278***	247,973
	(0.011)	(0.011)	(0.014)	
Minimum Price	-0.114***	-0.126***	-0.283***	246,974
	(0.010)	(0.009)	(0.015)	
Star-weighted Price (missing = 1)	-0.199***	-0.210***	-0.374***	247,930
	(0.061)	(0.062)	(0.073)	
Star-weighted Price (missing = 2.5)	-0.195***	-0.206***	-0.370***	247,999
	(0.061)	(0.063)	(0.074)	

Notes: The table replicates results of Table 4 on data aggregated to monthly frequency (instead of weekly). See notes to Table 4 for more details.

Appendix Table 6. Pass-through and speed of price adjustment.

Panel A: Pass-through

	Include only sellers with four or more star reviews		All sellers (Table 4)	
	Good Fixed effects	N	Good Fixed effects	N
	(1)	(2)	(3)	(4)
Mean Price	0.639***	671,598	0.698***	1,709,011
	(0.093)		(0.080)	
Median Price	0.634***	671,553	0.698***	1,708,982
	(0.094)		(0.082)	
Minimum Price	0.559***	670,272	0.677***	1,708,960
	(0.056)		(0.042)	
Star-weighted Price (missing = 1)	0.524***	671,047	0.614***	1,708,969
	(0.123)		(0.077)	
Star-weighted Price (missing = 2.5)	0.524***	671,047	0.642***	1,708,979
	(0.123)		(0.071)	

Panel B: Speed of Adjustment

	Include only sellers with four or more star reviews		All sellers (Table 4)	
	Good Fixed effects	N	Good Fixed effects	N
	(1)	(2)	(3)	(4)
Mean Price	-0.158***	426,045	-0.158***	885,150
	(0.007)		(0.005)	
Median Price	-0.179***	425,695	-0.170***	884,835
	(0.007)		(0.005)	
Minimum Price	-0.160***	424,749	-0.169***	883,912
	(0.006)		(0.005)	
Star-weighted Price (missing = 1)	-0.146***	425,428	-0.135***	886,115
	(0.008)		(0.012)	
Star-weighted Price (missing = 2.5)	-0.146***	425,428	-0.133***	886,292
	(0.008)		(0.042)	

Notes: Panel A presents estimates of α in specification (1). Panel B presents estimates of β in specification (2). Driscoll and Kraay (1998) standard errors are in parentheses. ***, **, * show statistical significance at the 1%, 5% and 10% levels.

Appendix Table 7. Descriptive statistics for standard deviation log(Price).

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	0.181	0.094	14	0.079	0.049	35
Antivirus software	0.187	0.095	20	0.150	0.123	39
Audio cables	0.277	0.167	82	0.361	0.179	86
Audio video utilities	0.162	0.148	75	0.084	0.073	107
AV accessories	0.114	0.061	40	0.142	0.051	49
Bags cases	0.169	0.114	26	0.150	0.094	25
Binoculars	0.273	0.098	18	0.107	0.064	83
Calculators	0.124	0.058	24	0.164	0.099	25
Camcorder accessories	0.238	0.122	15	0.138	0.067	18
Camcorder batteries power	0.273	0.139	22	0.186	0.122	30
Camcorders	0.089	0.043	19	0.089	0.041	20
Cases	0.118	0.077	243	0.145	0.064	260
Cash registers pos equipment	0.102	0.044	49	0.064	0.032	49
Computer games	0.446	0.268	45	0.304	0.263	78
Database management software	0.116	0.053	59	0.070	0.091	73
Dedicated flashes	0.169	0.108	23	0.079	0.053	44
Desktop computers	0.050	0.019	13	0.040	0.014	13
Digital cameras	0.114	0.057	44	0.095	0.047	48
Engineering and home design software	0.187	0.163	9	0.134	0.096	18
Financial and legal software	0.217	0.250	11	0.154	0.117	23
Flash memory	0.179	0.094	917	0.240	0.136	953
Flat panel and lcd monitors	0.058	0.028	275	0.067	0.024	282
GPS	0.106	0.064	58	0.126	0.069	69
Graphics and publishing software	0.123	0.101	623	0.119	0.103	678
Hard drives	0.103	0.058	161	0.167	0.076	168
Headphones	0.203	0.133	214	0.182	0.147	271
Hubs	0.095	0.080	674	0.127	0.085	706
Keyboards	0.122	0.055	242	0.172	0.073	244
Laptop	0.053	0.026	79	0.036	0.014	90
Laptop memory	0.151	0.074	1,248	0.178	0.091	1,275
Microphones and headsets	0.162	0.071	73	0.222	0.142	82
Miscellaneous programming software	0.179	0.178	109	0.083	0.106	115
Modems	0.156	0.166	89	0.177	0.139	98
Motherboards	0.098	0.098	655	0.090	0.069	708
Mp3 players	0.124	0.088	27	0.098	0.037	27
Network adapters	0.115	0.113	226	0.211	0.153	236
Office suites software	0.188	0.128	78	0.159	0.147	115
Plasma lcd televisions	0.088	0.031	25	0.084	0.047	32
Portable device accessories	0.195	0.130	226	0.235	0.168	262
Power supplies	0.100	0.065	402	0.126	0.081	444
Processors in retail box	0.062	0.049	518	0.131	0.096	544
Projection screens	0.185	0.105	29	0.171	0.064	29
Projectors	0.083	0.058	390	0.083	0.046	416
Scanners	0.066	0.044	602	0.081	0.052	650
Security software	0.095	0.081	118	0.159	0.096	125
SLR lenses	0.094	0.053	171	0.055	0.037	386
Speakers	0.128	0.068	157	0.152	0.091	171
Storage media	0.145	0.086	245	0.250	0.118	247
System utilities software	0.110	0.101	49	0.115	0.088	33
Tripods	0.211	0.068	22	0.123	0.097	22
Tv accessories and mounts	0.128	0.056	26	0.164	0.059	27
UPSS	0.067	0.038	657	0.101	0.051	694
Video cables	0.240	0.148	545	0.324	0.168	595
Webcams	0.158	0.102	65	0.151	0.079	69
Windows operating system software	0.132	0.125	155	0.110	0.102	213

Appendix Table 8. Descriptive statistics for median log(Price).

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	4.936	0.940	35	4.687	1.088	35
Antivirus software	3.996	0.907	52	3.942	0.864	52
Audio cables	2.960	0.837	86	3.012	0.722	86
Audio video utilities	5.170	0.810	113	5.141	0.838	113
AV accessories	5.237	0.944	57	5.187	0.990	57
Bags cases	4.455	0.889	29	4.268	0.913	29
Binoculars	5.155	1.043	90	5.209	0.995	90
Calculators	3.800	0.989	26	3.456	1.010	26
Camcorder accessories	4.553	0.819	18	4.369	0.881	18
Camcorder batteries power	4.497	0.474	30	4.322	0.455	30
Camcorders	5.601	1.052	20	5.555	1.044	20
Cases	4.822	0.735	261	4.707	0.739	261
Cash registers pos equipment	5.272	0.405	49	5.220	0.394	49
Computer games	2.745	0.823	144	2.475	0.987	144
Database management software	7.088	1.641	100	7.006	1.662	100
Dedicated flashes	5.115	0.778	49	5.060	0.694	49
Desktop computers	6.863	0.638	13	6.753	0.601	13
Digital cameras	6.028	0.707	48	5.900	0.697	48
Engineering and home design software	5.851	1.583	24	5.902	1.496	24
Financial and legal software	5.525	1.319	26	5.444	1.332	26
Flash memory	3.688	0.871	976	3.645	0.838	976
Flat panel and lcd monitors	5.906	0.803	283	5.833	0.789	283
GPS	5.186	0.722	70	5.075	0.775	70
Graphics and publishing software	5.850	1.027	734	5.760	0.991	734
Hard drives	5.291	0.779	168	5.187	0.687	168
Headphones	4.076	0.936	274	3.814	1.064	274
Hubs	6.449	1.741	710	6.330	1.714	710
Keyboards	4.058	0.655	244	3.977	0.658	244
Laptop	6.169	0.539	90	6.172	0.499	90
Laptop memory	4.395	0.831	1,285	4.290	0.778	1,285
Microphones and headsets	3.865	0.918	82	3.692	0.906	82
Miscellaneous programming software	7.066	1.222	147	6.923	1.245	147
Modems	4.230	1.299	99	4.174	1.211	99
Motherboards	5.195	0.674	721	5.136	0.685	721
Mp3 players	4.737	0.766	27	4.719	0.754	27
Network adapters	5.118	1.299	236	4.964	1.248	236
Office suites software	5.409	0.663	121	5.280	0.665	121
Plasma lcd televisions	6.337	0.749	32	6.270	0.725	32
Portable device accessories	3.504	0.926	277	3.482	0.893	277
Power supplies	4.872	0.868	452	4.780	0.823	452
Processors in retail box	6.144	0.901	570	5.950	0.816	570
Projection screens	5.498	0.869	30	5.410	0.932	30
Projectors	6.938	0.748	418	6.852	0.729	418
Scanners	5.801	0.972	654	5.715	0.950	654
Security software	3.816	1.205	168	3.752	1.115	168
SLR lenses	6.434	0.710	390	6.348	0.710	390
Speakers	4.252	0.872	174	4.159	0.858	174
Storage media	3.669	0.949	247	3.435	0.978	247
System utilities software	5.646	1.683	63	5.592	1.708	63
Tripods	5.295	0.982	24	5.084	1.054	24
Tv accessories and mounts	4.922	0.761	27	4.782	0.698	27
UPSS	6.135	1.155	698	6.026	1.158	698
Video cables	3.172	0.913	601	3.131	0.840	601
Webcams	4.124	0.617	72	4.001	0.617	72
Windows operating system software	6.009	1.095	223	5.902	1.124	223

Appendix Table 9. Descriptive statistics for frequency of price chance.

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	0.422	0.398	35	0.067	0.041	35
Antivirus software	0.222	0.206	52	0.138	0.144	52
Audio cables	0.185	0.119	86	0.102	0.040	86
Audio video utilities	0.453	0.310	113	0.135	0.126	113
AV accessories	0.288	0.170	57	0.125	0.106	57
Bags cases	0.189	0.240	29	0.111	0.090	29
Binoculars	0.723	0.256	90	0.063	0.047	90
Calculators	0.174	0.096	26	0.064	0.038	26
Camcorder accessories	0.342	0.243	18	0.113	0.093	18
Camcorder batteries power	0.422	0.269	30	0.148	0.077	30
Camcorders	0.390	0.167	20	0.271	0.165	20
Cases	0.286	0.143	261	0.169	0.082	261
Cash registers pos equipment	0.515	0.112	49	0.094	0.038	49
Computer games	0.248	0.193	144	0.107	0.111	144
Database management software	0.149	0.172	100	0.116	0.101	100
Dedicated flashes	0.581	0.348	49	0.089	0.072	49
Desktop computers	0.373	0.202	13	0.421	0.122	13
Digital cameras	0.190	0.129	48	0.212	0.113	48
Engineering and home design software	0.240	0.219	24	0.154	0.111	24
Financial and legal software	0.241	0.172	26	0.176	0.123	26
Flash memory	0.298	0.162	976	0.214	0.113	976
Flat panel and lcd monitors	0.360	0.157	283	0.306	0.109	283
GPS	0.266	0.160	70	0.109	0.058	70
Graphics and publishing software	0.328	0.214	734	0.165	0.103	734
Hard drives	0.329	0.159	168	0.282	0.089	168
Headphones	0.239	0.222	274	0.081	0.060	274
Hubs	0.324	0.197	710	0.209	0.082	710
Keyboards	0.308	0.159	244	0.188	0.074	244
Laptop	0.373	0.125	90	0.282	0.121	90
Laptop memory	0.440	0.187	1,285	0.316	0.105	1,285
Microphones and headsets	0.241	0.126	82	0.135	0.069	82
Miscellaneous programming software	0.200	0.202	147	0.169	0.149	147
Modems	0.335	0.184	99	0.163	0.075	99
Motherboards	0.312	0.167	721	0.227	0.104	721
Mp3 players	0.447	0.166	27	0.134	0.066	27
Network adapters	0.328	0.164	236	0.213	0.092	236
Office suites software	0.209	0.141	121	0.209	0.124	121
Plasma lcd televisions	0.405	0.226	32	0.242	0.124	32
Portable device accessories	0.253	0.176	277	0.135	0.090	277
Power supplies	0.275	0.149	452	0.179	0.082	452
Processors in retail box	0.287	0.154	570	0.211	0.095	570
Projection screens	0.242	0.139	30	0.099	0.073	30
Projectors	0.291	0.202	418	0.217	0.098	418
Scanners	0.460	0.183	654	0.144	0.102	654
Security software	0.217	0.142	168	0.088	0.094	168
SLR lenses	0.627	0.311	390	0.080	0.056	390
Speakers	0.297	0.187	174	0.169	0.081	174
Storage media	0.170	0.105	247	0.133	0.068	247
System utilities software	0.155	0.158	63	0.114	0.145	63
Tripods	0.273	0.131	24	0.078	0.076	24
Tv accessories and mounts	0.377	0.260	27	0.127	0.048	27
UPSS	0.295	0.154	698	0.205	0.069	698
Video cables	0.188	0.161	601	0.146	0.066	601
Webcams	0.317	0.180	72	0.203	0.092	72
Windows operating system software	0.218	0.160	223	0.181	0.101	223

Appendix Table 10. Descriptive statistics for median duration of price spell (procedure C).

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	11.200	23.842	35	7.343	6.905	35
Antivirus software	6.510	6.485	52	15.529	24.453	52
Audio cables	1.657	0.768	86	3.942	4.846	86
Audio video utilities	2.221	4.844	113	6.783	9.795	113
AV accessories	1.763	1.418	57	12.553	18.544	57
Bags cases	12.776	23.004	29	6.741	7.074	29
Binoculars	1.017	0.117	90	7.706	10.330	90
Calculators	2.462	0.811	26	5.731	7.319	26
Camcorder accessories	1.222	0.732	18	6.194	9.204	18
Camcorder batteries power	1.083	0.324	30	2.750	1.696	30
Camcorders	1.200	0.523	20	2.500	2.969	20
Cases	1.981	2.594	261	2.852	2.668	261
Cash registers pos equipment	1.061	0.242	49	4.469	2.875	49
Computer games	2.840	3.190	144	9.660	13.934	144
Database management software	15.635	25.329	100	15.455	25.393	100
Dedicated flashes	1.469	2.218	49	10.827	23.029	49
Desktop computers	1.692	0.855	13	1.000	0.000	13
Digital cameras	6.438	16.192	48	2.375	1.925	48
Engineering and home design software	4.062	4.121	24	8.250	19.383	24
Financial and legal software	4.808	8.138	26	7.904	14.679	26
Flash memory	2.599	8.124	976	2.877	4.922	976
Flat panel and lcd monitors	1.269	0.723	283	1.299	0.601	283
GPS	4.879	20.092	70	4.086	2.364	70
Graphics and publishing software	5.372	15.696	734	7.824	19.640	734
Hard drives	1.348	1.324	168	1.262	0.713	168
Headphones	3.858	7.591	274	8.048	12.839	273
Hubs	2.342	4.782	710	2.258	1.295	710
Keyboards	1.740	2.792	244	2.242	1.389	244
Laptop	1.156	0.523	90	1.550	0.868	90
Laptop memory	1.496	4.822	1,285	1.508	0.878	1,285
Microphones and headsets	2.128	2.577	82	3.012	2.839	82
Miscellaneous programming software	15.524	26.633	147	14.255	26.459	147
Modems	2.045	2.600	99	2.702	3.033	99
Motherboards	2.298	3.443	721	2.550	2.712	721
Mp3 players	1.000	0.000	27	3.667	3.442	27
Network adapters	1.695	1.202	236	2.216	1.535	236
Office suites software	4.492	8.485	121	4.570	9.960	121
Plasma lcd televisions	1.891	2.249	32	1.672	1.082	32
Portable device accessories	4.078	9.910	277	4.567	8.136	277
Power supplies	2.134	2.680	452	3.009	3.589	452
Processors in retail box	5.584	21.903	570	2.735	3.549	570
Projection screens	1.483	0.951	30	11.450	16.587	30
Projectors	4.124	18.846	418	1.914	1.894	418
Scanners	1.440	2.225	654	3.640	4.183	654
Security software	4.024	4.678	168	22.057	25.694	168
SLR lenses	1.121	1.282	390	7.362	8.772	390
Speakers	3.124	11.433	174	3.264	5.928	174
Storage media	2.119	1.490	247	2.682	1.626	247
System utilities software	6.008	10.259	63	15.317	16.684	63
Tripods	6.271	24.662	24	12.458	22.951	24
Tv accessories and mounts	2.519	3.059	27	2.519	1.114	27
UPSS	1.742	1.291	698	2.332	2.883	698
Video cables	2.810	4.265	601	3.193	4.949	601
Webcams	1.951	2.140	72	1.986	0.866	71
Windows operating system software	4.103	5.158	223	3.818	4.164	223

Appendix Table 11. Descriptive statistics for median abs(dlog(Price)).

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	0.072	0.182	30	0.085	0.048	33
Antivirus software	0.063	0.074	50	0.070	0.074	43
Audio cables	0.069	0.077	86	0.052	0.053	85
Audio video utilities	0.031	0.057	111	0.067	0.106	105
AV accessories	0.031	0.049	57	0.032	0.035	44
Bags cases	0.041	0.036	27	0.044	0.044	29
Binoculars	0.014	0.008	90	0.077	0.071	87
Calculators	0.065	0.041	26	0.058	0.050	26
Camcorder accessories	0.021	0.021	18	0.042	0.036	17
Camcorder batteries power	0.013	0.007	30	0.047	0.036	30
Camcorders	0.059	0.051	20	0.070	0.054	20
Cases	0.055	0.082	260	0.038	0.028	259
Cash registers pos equipment	0.016	0.003	49	0.022	0.013	49
Computer games	0.121	0.135	144	0.176	0.160	131
Database management software	0.036	0.046	86	0.036	0.044	86
Dedicated flashes	0.013	0.014	49	0.051	0.037	45
Desktop computers	0.018	0.007	13	0.016	0.006	13
Digital cameras	0.083	0.080	47	0.063	0.034	48
Engineering and home design software	0.061	0.054	24	0.065	0.090	23
Financial and legal software	0.072	0.192	26	0.057	0.049	24
Flash memory	0.049	0.060	969	0.053	0.045	969
Flat panel and lcd monitors	0.023	0.013	283	0.025	0.014	283
GPS	0.043	0.036	68	0.042	0.023	70
Graphics and publishing software	0.025	0.036	701	0.028	0.037	683
Hard drives	0.038	0.029	168	0.043	0.016	168
Headphones	0.113	0.135	270	0.080	0.069	266
Hubs	0.037	0.062	704	0.025	0.021	710
Keyboards	0.037	0.037	244	0.038	0.020	244
Laptop	0.022	0.013	90	0.020	0.010	90
Laptop memory	0.044	0.042	1,284	0.054	0.021	1,285
Microphones and headsets	0.057	0.057	82	0.051	0.043	81
Miscellaneous programming software	0.026	0.023	128	0.026	0.031	127
Modems	0.041	0.045	99	0.033	0.024	98
Motherboards	0.036	0.048	710	0.026	0.020	717
Mp3 players	0.018	0.009	27	0.039	0.021	27
Network adapters	0.030	0.035	236	0.030	0.024	236
Office suites software	0.052	0.087	121	0.052	0.089	119
Plasma lcd televisions	0.059	0.039	32	0.034	0.016	32
Portable device accessories	0.066	0.092	269	0.063	0.079	270
Power supplies	0.046	0.039	449	0.035	0.032	449
Processors in retail box	0.028	0.040	554	0.034	0.048	570
Projection screens	0.020	0.011	30	0.031	0.016	25
Projectors	0.030	0.040	409	0.019	0.017	418
Scanners	0.019	0.018	653	0.020	0.020	647
Security software	0.030	0.037	168	0.076	0.053	131
SLR lenses	0.014	0.008	390	0.065	0.046	388
Speakers	0.042	0.037	173	0.054	0.070	173
Storage media	0.057	0.042	247	0.056	0.044	247
System utilities software	0.030	0.040	61	0.028	0.032	52
Tripods	0.026	0.033	23	0.079	0.068	22
Tv accessories and mounts	0.066	0.120	27	0.039	0.038	27
UPSS	0.021	0.024	698	0.020	0.015	696
Video cables	0.072	0.071	599	0.045	0.034	598
Webcams	0.047	0.039	72	0.053	0.032	71
Windows operating system software	0.043	0.066	221	0.047	0.083	223

Appendix Table 12. Descriptive statistics for synchronization of price changes.

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	0.052	0.185	13	0.099	0.101	33
Antivirus software	0.335	0.253	20	0.175	0.099	37
Audio cables	0.166	0.101	82	0.097	0.068	85
Audio video utilities	0.238	0.171	73	0.109	0.096	98
AV accessories	0.204	0.198	40	0.186	0.116	43
Bags cases	0.067	0.109	23	0.120	0.106	25
Binoculars	0.018	0.054	18	0.073	0.074	80
Calculators	0.225	0.156	24	0.093	0.056	25
Camcorder accessories	0.095	0.132	15	0.135	0.099	17
Camcorder batteries power	0.072	0.047	22	0.161	0.133	30
Camcorders	0.208	0.183	19	0.236	0.112	19
Cases	0.273	0.204	234	0.180	0.096	258
Cash registers pos equipment	0.540	0.123	49	0.111	0.047	49
Computer games	0.205	0.207	46	0.066	0.143	62
Database management software	0.248	0.245	57	0.157	0.136	70
Dedicated flashes	0.060	0.105	23	0.071	0.085	40
Desktop computers	0.396	0.176	13	0.277	0.194	13
Digital cameras	0.132	0.135	42	0.218	0.126	48
Engineering and home design software	0.288	0.319	9	0.110	0.105	18
Financial and legal software	0.113	0.100	10	0.171	0.095	23
Flash memory	0.274	0.175	915	0.201	0.108	942
Flat panel and lcd monitors	0.361	0.183	274	0.308	0.110	282
GPS	0.336	0.186	57	0.103	0.059	69
Graphics and publishing software	0.324	0.204	606	0.144	0.093	643
Hard drives	0.367	0.164	161	0.326	0.089	168
Headphones	0.119	0.139	212	0.086	0.096	260
Hubs	0.315	0.235	670	0.186	0.085	706
Keyboards	0.284	0.157	240	0.201	0.079	244
Laptop	0.283	0.148	78	0.290	0.128	90
Laptop memory	0.458	0.186	1,248	0.347	0.119	1,273
Microphones and headsets	0.242	0.159	73	0.114	0.061	81
Miscellaneous programming software	0.238	0.228	100	0.194	0.147	112
Modems	0.296	0.234	89	0.146	0.079	98
Motherboards	0.311	0.211	647	0.196	0.106	706
Mp3 players	0.304	0.155	27	0.162	0.097	27
Network adapters	0.360	0.218	227	0.183	0.079	235
Office suites software	0.183	0.163	76	0.182	0.122	113
Plasma lcd televisions	0.376	0.244	25	0.249	0.162	32
Portable device accessories	0.203	0.200	224	0.127	0.094	259
Power supplies	0.264	0.204	402	0.166	0.100	440
Processors in retail box	0.277	0.186	508	0.186	0.088	541
Projection screens	0.174	0.206	29	0.147	0.084	25
Projectors	0.259	0.207	381	0.216	0.102	413
Scanners	0.464	0.212	601	0.130	0.087	644
Security software	0.169	0.161	118	0.173	0.096	121
SLR lenses	0.075	0.156	170	0.134	0.099	381
Speakers	0.246	0.176	157	0.158	0.097	171
Storage media	0.262	0.108	245	0.149	0.077	247
System utilities software	0.097	0.175	49	0.134	0.190	33
Tripods	0.040	0.069	22	0.113	0.124	21
Tv accessories and mounts	0.336	0.220	26	0.130	0.059	27
UPSS	0.334	0.189	656	0.190	0.065	690
Video cables	0.136	0.139	541	0.119	0.073	591
Webcams	0.208	0.162	65	0.199	0.077	69
Windows operating system software	0.238	0.176	154	0.168	0.120	210

Appendix Table 13. Descriptive statistics for number of sellers.

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	1.204	0.298	35	2.053	0.910	35
Antivirus software	1.344	0.988	52	2.572	2.000	52
Audio cables	1.865	0.572	86	2.474	0.765	86
Audio video utilities	1.769	1.023	113	2.938	1.740	113
AV accessories	2.015	0.963	57	3.434	2.026	57
Bags cases	1.562	0.565	29	2.308	1.104	29
Binoculars	1.127	0.530	90	2.327	0.939	90
Calculators	2.053	0.987	26	3.273	1.116	26
Camcorder accessories	1.692	0.617	18	2.321	0.789	18
Camcorder batteries power	1.876	0.917	30	2.583	0.857	30
Camcorders	1.657	0.546	20	2.293	1.305	20
Cases	2.338	1.437	261	3.823	1.373	261
Cash registers pos equipment	1.755	0.244	49	3.298	0.788	49
Computer games	1.158	0.429	144	1.438	0.857	144
Database management software	1.669	1.364	100	2.025	1.181	100
Dedicated flashes	1.385	0.594	49	1.960	1.191	49
Desktop computers	2.768	1.223	13	2.453	1.215	13
Digital cameras	1.843	0.725	48	3.017	1.497	48
Engineering and home design software	1.794	1.821	24	2.353	1.913	24
Financial and legal software	1.710	1.384	26	3.771	2.111	26
Flash memory	2.518	1.214	976	3.014	1.266	976
Flat panel and lcd monitors	2.246	0.867	283	2.620	0.838	283
GPS	2.233	1.099	70	4.467	1.929	70
Graphics and publishing software	2.641	1.653	734	4.030	2.733	734
Hard drives	2.489	1.144	168	4.564	2.421	168
Headphones	1.675	0.989	274	2.994	1.353	274
Hubs	2.406	1.111	710	5.832	2.875	710
Keyboards	2.814	1.083	244	4.082	1.276	244
Laptop	1.844	0.670	90	2.097	0.623	90
Laptop memory	3.313	1.226	1,285	3.623	1.463	1,285
Microphones and headsets	2.784	1.905	82	3.418	1.213	82
Miscellaneous programming software	2.102	1.873	147	3.014	2.967	147
Modems	2.182	1.251	99	3.358	1.282	99
Motherboards	2.752	1.520	721	3.207	1.258	721
Mp3 players	1.550	0.352	27	2.408	1.211	27
Network adapters	2.688	1.065	236	4.716	2.322	236
Office suites software	1.976	1.654	121	3.377	2.311	121
Plasma lcd televisions	1.685	0.772	32	1.859	0.416	32
Portable device accessories	1.909	0.937	277	3.068	1.402	277
Power supplies	2.300	1.207	452	3.096	1.436	452
Processors in retail box	2.529	1.294	570	3.761	1.819	570
Projection screens	1.779	0.783	30	2.845	1.217	30
Projectors	2.518	1.131	418	4.329	1.604	418
Scanners	2.009	1.054	654	4.300	1.746	654
Security software	1.406	0.652	168	2.057	1.504	168
SLR lenses	1.254	0.391	390	2.415	1.164	390
Speakers	2.842	1.836	174	3.192	1.297	174
Storage media	3.244	0.950	247	5.474	2.563	247
System utilities software	1.336	0.672	63	1.824	1.435	63
Tripods	1.846	0.687	24	1.808	0.743	24
Tv accessories and mounts	1.744	0.525	27	4.371	1.597	27
UPSS	2.874	1.361	698	4.810	1.887	698
Video cables	2.236	0.889	601	3.364	1.094	601
Webcams	2.459	1.692	72	4.201	1.788	72
Windows operating system software	1.816	1.123	223	2.924	1.800	223

Appendix Table 14. Descriptive statistics for stability of sellers.

Category	Canada			US		
	Mean	SD	N	Mean	SD	N
35mm slr lens accessories	0.706	0.281	35	0.373	0.155	35
Antivirus software	0.569	0.229	52	0.531	0.277	52
Audio cables	0.304	0.135	86	0.285	0.097	86
Audio video utilities	0.597	0.287	113	0.466	0.216	113
AV accessories	0.374	0.128	57	0.402	0.133	57
Bags cases	0.470	0.115	29	0.373	0.130	29
Binoculars	0.830	0.234	90	0.438	0.209	90
Calculators	0.258	0.062	26	0.319	0.171	26
Camcorder accessories	0.421	0.136	18	0.348	0.184	18
Camcorder batteries power	0.439	0.207	30	0.291	0.136	30
Camcorders	0.358	0.184	20	0.331	0.073	20
Cases	0.399	0.152	261	0.424	0.170	261
Cash registers pos equipment	0.391	0.098	49	0.580	0.092	49
Computer games	0.806	0.268	144	0.639	0.305	144
Database management software	0.653	0.305	100	0.624	0.269	100
Dedicated flashes	0.684	0.304	49	0.378	0.221	49
Desktop computers	0.411	0.143	13	0.338	0.086	13
Digital cameras	0.491	0.188	48	0.412	0.140	48
Engineering and home design software	0.740	0.266	24	0.546	0.295	24
Financial and legal software	0.742	0.288	26	0.497	0.235	26
Flash memory	0.396	0.173	976	0.419	0.192	976
Flat panel and lcd monitors	0.253	0.069	283	0.273	0.083	283
GPS	0.346	0.193	70	0.361	0.119	70
Graphics and publishing software	0.493	0.233	734	0.503	0.219	734
Hard drives	0.285	0.083	168	0.290	0.080	168
Headphones	0.451	0.222	274	0.369	0.152	274
Hubs	0.386	0.163	710	0.422	0.180	710
Keyboards	0.324	0.109	244	0.340	0.126	244
Laptop	0.366	0.073	90	0.367	0.073	90
Laptop memory	0.410	0.138	1,285	0.356	0.136	1,285
Microphones and headsets	0.355	0.156	82	0.323	0.129	82
Miscellaneous programming software	0.556	0.281	147	0.523	0.292	147
Modems	0.354	0.181	99	0.350	0.134	99
Motherboards	0.466	0.174	721	0.449	0.162	721
Mp3 players	0.285	0.114	27	0.307	0.092	27
Network adapters	0.312	0.140	236	0.323	0.136	236
Office suites software	0.590	0.306	121	0.414	0.198	121
Plasma lcd televisions	0.326	0.107	32	0.283	0.076	32
Portable device accessories	0.423	0.201	277	0.473	0.194	277
Power supplies	0.399	0.182	452	0.396	0.163	452
Processors in retail box	0.386	0.182	570	0.397	0.182	570
Projection screens	0.397	0.220	30	0.356	0.185	30
Projectors	0.403	0.167	418	0.391	0.127	418
Scanners	0.358	0.170	654	0.431	0.169	654
Security software	0.443	0.128	168	0.654	0.223	168
SLR lenses	0.716	0.272	390	0.343	0.134	390
Speakers	0.392	0.187	174	0.374	0.177	174
Storage media	0.295	0.073	247	0.303	0.090	247
System utilities software	0.582	0.244	63	0.718	0.304	63
Tripods	0.600	0.242	24	0.397	0.238	24
Tv accessories and mounts	0.340	0.173	27	0.397	0.146	27
UPSS	0.291	0.132	698	0.283	0.124	698
Video cables	0.409	0.172	601	0.452	0.176	601
Webcams	0.423	0.161	72	0.448	0.172	72
Windows operating system software	0.541	0.312	223	0.416	0.200	223